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NUCLEAR POWER TECHNOLOGY AND COSTS

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I. Introduction

1. Nuclear power has now achieved a state of development and experience such that it warrants serious consideration in connection with planning future growth of power systems. There are undoubtedly many situations in the world in which a clear economic justification can be made for nuclear power plants. Likewise, of course, many situations which may appear to be favorable to nuclear power on the basis of a superficial analysis will not be economically favorable when the situation is analyzed in greater detail. Even in areas in which nuclear power does not appear to be economically justified at the present time there may be good reasons to gain some experience with nuclear power plants now in order to have a solid foundation upon which to build a nuclear power industry which will be economically attractive in the future. On the other hand, a premature or poorly directed nuclear power plant construction program can be wasteful of valuable national efforts.

2. It is the intent of this paper to review briefly the status of nuclear power plant technology based upon experience in the United States with particular reference to possible application of that experience to the needs of less developed areas. The definition of "less developed areas" is clearly a relative matter. Some areas of the United States, for example, are less developed than other areas. Thus, some evaluation of nuclear power for less developed areas can be made within national boundaries. Even more important, and certainly more complicated, is the evaluation of nuclear power for countries which are "less developed."

3. Nuclear power has many different energy applications. Its development thus far has been primarily for the production of electricity because this application requires relatively large plants that appear economically favorable to nuclear power. Production of electricity also appears to be the application of most immediate interest to less developed countries. Frequently the distinguishing features of such countries are relatively low per capita income and relatively low per capita consumption of electricity. This observation naturally leads to a common impression that there is a direct correlation between use of electricity and income. A closer look, however, shows that the correlation is not exact. Increased standards of living are not achieved simply by increasing electric power supply. A low ratio of electric power consumption per unit of national income, which is charateristic of less-developed countries, is the result of an interplay of many factors. These factors include, for example, limited or undeveloped resources, low industrialization with low power demands, and high fuel costs with high electric generating costs. Figure I (compiled from data given in the United Nations Statistical Yearbook, 1960) is an illustration of the irregular correlation and importance of these factors. Note that Canada, Norway and Japan all have higher rates

of electricity consumption per unit of income than the United States but their per capita incomes are lower. The general conclusion from such an evaluation of factors contributing to the state of development of an area is that availability and cost of fuel are very important.

4. Nuclear fuel has characteristics which make it unique for equalizing the cost of fuel in various geographical areas. It is natural, therefore, that countries which have been relatively slow in their development because of scarcity or cost of fuel look with interest toward nuclear power.

II. Status of Nuclear Power Technology

5. The results of research and development, design, construction and operation of nuclear power reactors in the United States have been widely reported.[1-10] This experience includes a wider range of reactor concepts than that of any other country. Nevertheless, the results of work in other countries also are very important and should be considered in the planning of any future program. The class of reactors using ordinary water as moderator and coolant has had the most extensive developmental support in the United States. There are several design variations within the class, extending from those which permit no net steam generation in the core to those which have all steam generated in the core and passed directly to the turbine. Variations in control scheme and fuel management also are available. The specific choice of design and mode of operation should depend upon the size plant required and other considerations related to the specific application including, of course, the financial arrangement offered for its construction.

6. In the United States current plant construction bids, fuel guarantees, and applicable government policies permit construction of plants in the range of a few hundreds of megawatts of electrical capacity which should be competitive with fossil fueled plants in areas where fossil fuel costs are 35¢ per million BTU and perhaps even slightly less. In general, the economics of nuclear plants relative to fossil fueled plants becomes less favorable as the plant size decreases. In other words, the fossil fuel costs at which nuclear power may be competitive decreases with increasing nuclear plant size. The relatively higher proportion of nuclear power costs which are due to capital costs also makes the comparison somewhat sensitive to the plant capacity factor to be expected and the fixed charge rate considered applicable. The currently estimated levels of fossil fuel costs at which nuclear power could be competitive in the United States, for plants up to 100 MWE, is shown in Figure II.

7. Confidence in the reliability and dependability of nuclear plants of the water-moderated and cooled variety is based upon the record established by the three such plants which have now been operated fairly extensively as power producers on utility systems in the United States. These plants are the pressurized water reactors at Shippingport, Pennsylvania, (Duquesne Light Company System) and Rowe, Massachusetts, (Yankee Nuclear Power Station) and the boiling water reactor at Dresden, Illinois (Commonwealth Edison Company).[8,9]

8. The pressurized water reactor at Shippingport, Pennsylvania, completed two 1000-hour full power (60,000 KWe) runs with the first seed of its seed-blanket core in 1958 and three 1300-hour full power runs with the second seed during 1961. Numerous reactor plant and core tests as well as training exercises were conducted during these intervals. Despite extensive low power operation required for test programs and training during operation with the second seed, gross electric power generation amounted to 514,300,000 kwh - equivalent to operating the plant at full power 70 per cent of the time. Shutdowns for maintenance accounted for less than 3 per cent of the time. The Shippingport station has followed all system load change demands, and has proved it can be shut down and started up under controlled conditions at a faster rate than any modern conventional power plant on the system of the Duquesne Light Company.

9. The Yankee Nuclear Power Station completed operation with its first core on May 18, 1962, after 8600 equivalent reactor hours at 485 MW thermal. During this time gross electric power generation amounted to 1,330,521,000 kwh. This performance is equivalent to operating the plant at full power 68.6 per cent of the time. Plant and core test programs limited the plant load factor, but the reactor was at operating temperature and pressure 90 per cent of the time. The start up of the Yankee plant was accompanied by outages due to steam turbine vibrations and design modifications to the throttle valves and generator control systems. However, only about one week of outage was directly attributable to the nuclear plant, that being due to valve stem leakage.

10. The Dresden Nuclear Power Station has been in service since April, 1960. By September, 1962, gross electric power generation amounted to 1,797,677,000 kwh. There were two unplanned outages attributable to the nuclear plant during this initial operating period. Conditions causing these outages were remedied by design changes to materials in the control rod drives and in the control blades. Following resumption of operation after the outage ending in December, 1961, including the period to September, 1962, reactor availability has been 94.7 per cent, plant availability 92 per cent, and plant capacity factor 85.5 per cent. Since part of the steam in this plant is generated in the core and goes directly to the turbine, it is worth noting that radiation surveys have confirmed experience at the Experimental Boiling Water Reactor and the Vallecitos Boiling Water Reactor, all of which shows only a negligible amount of turbine contamination caused by radioactive corrosion products from the reactor system.

11. Experience with all three of these plants has shown that shielding has been conservatively designed, and radioactive waste release has been far less than permissible limits. Experience also has demonstrated that each of the reactors is capable of much higher outputs than provided in the original design specification. For example, modifications in the Shippingport plant are planned which will increase its output from 68,000 KWE gross to the equivalent of 150,000 KWE gross, using essentially the same pressure vessel but with a one-foot extension in height. The power output from the first core at Yankee was increased progressively from 110 KWE to 141 MWE, and operation with the second core currently is authorized at 155 MWE. The rating of the Dresden plant also progressed from an initial design of 180 MWE to a currently authorized power level equivalent to at least 200 MWE.

12. Operating experience with these major nuclear power producers is continuing to provide the basis for confidence and improvements in future nuclear power plants. More plants representing markedly different technologies are nearing their operating phase. Meanwhile, increased experience and volume in fuel fabrication is providing a basis for commercial fuel cycle guarantees which point toward nuclear fuel cycle costs of the order of 2.0 to 2.5 mills per kwh in the very near future. These figures are expected to drop to 1.0 to 1.5 mills per kwh within 10 years even with accounting practices that would go with private ownership of nuclear fuel, commercial reprocessing, and recycle of plutonium at fuel value.

III. Pattern of Nuclear Power Use in the United States

13. As indicated earlier, the United States has areas representing rather widely differing degrees of development. Therefore, it is of interest to observe the pattern of developing interest in nuclear power. Three different bases for interest in nuclear power are apparent in the United States, excluding interests stimulated by reasons other than evaluation of economic promise.

14. The most prominent basis of interest is in areas which are already highly industrialized to the point where large power plants are warranted but in which fuel costs, for one reason or another, are relatively high. Examples of these areas include the New England States, California and the North Central States.

15. Next, there is interest in providing nuclear power plants on large integrated power grids but located at the periphery of these grids, where the local power demands are still modest and fuel costs are high because of relative remoteness of the site from fuel resources. This situation is examplified, for example, by the Big Rock Point Plant of Consumers Power of Michigan and by the Pathfinder Plant of Northern States Power Company.

16. Finally there is interest in nuclear power in very isolated places, even though quite small plants might be required. The outstanding example of this application by the United States is the location of a nuclear power plant of 1500 KWe capacity at McMurdo Sound, and plans for installation of similar small plants at other sites in Antarctica and elsewhere.

17. Each of these three types of interest is soundly based in terms of attempting to provide most effective use of available energy resources with consideration of the many factors involved in making such evaluations.

18. The long term interest of the United States in nuclear power development is to make possible the realization of the full energy potential of nuclear fuels and thus to make it possible for these fuels to provide the nation's power needs for many centuries. Projections of power requirements against various fuel resources indicate that early in the twenty-first century the United States should be prepared to have all new increments of power generating capacity supplied from nuclear plants.

IV. Bases for Interest in Less Developed Countries

19. The World Power Conference Survey of Energy Resources, 1962[13] summarizes the situation on total energy resources as follows:

> ".....it is interesting to estimate the coal equivalent of the reserves of the fossil fuels - coal, brown coal and lignite, peat, petroleum, oil in shale and bituminous sand, and natural gas - that could probably be economically recovered. The coal equivalents are 3 million million tonnes for coal, brown coal and lignite, 100,000 million tonnes for peat, 90,000 million tonnes for petroleum, 200,000 million tonnes for oil in shale and bituminous sand, and 90,000 million tonnes for natural gas or a total coal equivalent of about 3.5 million million tonnes for all these resources. This quantity is 700 to 800 times the coal equivalent of the whole of the fuel and energy used annually by the world at the present time.....
>
> "In addition, there are the enormous amounts of energy to be derived from nuclear fission and probably also from nuclear fusion.....
>
> "It is thus clear that for the world as a whole there is no shortage of energy. The problem is one of economics. Costs must differ considerably in different areas owing to the uneven distribution of resources and the heavy costs often involved in the transport of materials and energy in their various forms....."

20. The ratio of fossil fuel reserves to the current rate of consumption is put in somewhat different perspective when one recognizes that highly developed areas have a per capita energy consumption rate of about 6 times the world average and that electric power consumption rates in general are doubling approximately every 10 years. Thus, if all areas were using energy at the same rate as the United States, for example, and if growth rates continued as at present, the fossil fuels referred to above would be adequate for only three or four decades - comparable to the expected lifetime of a power plant.

21. For the short term the emphasis clearly must be a choice among the alternative fuels to provide the most favorable economics - which, in turn, if properly evaluated, implies the most effective use of resources. The analysis necessary to make that choice generally is not a simple one. It must be made for specific situations by persons having intimate knowledge of pertinent local factors and persons with expert knowledge of the most modern technologies related to the use of the alternate fuels. Enlightened consideration of nuclear power in such evaluations has been greatly aided by the work of the International Atomic Energy Agency, which, in response to requests of various countries, has sent special missions of qualified people to study local situations. Each of these studies results in a fairly detailed report.[14,15,16] Other important studies of this type have been done by individual countries and at least in some areas, such as India and Brazil, it has been determined that nuclear power is economically attractive now. It is not possible in this paper to do a satisfactory job of digesting the various reports on the applicability of nuclear power for less developed areas, yet these areas represent only a small fraction of those which warrant study. A few general observations can be made, however, which may be helpful in determining whether or not more serious studies are warranted and in avoiding premature optimism and enthusiasm.

(a) Fossil fuel costs which appear to be high may be artificially imposed; while consideration of nuclear power in these cases may lead to reduction in fossil fuel prices, construction of the nuclear plant may not be economically justified when realistic fossil fuel costs are reflected.

(b) High power costs due to small plants operating a relatively small fraction of the time are not likely to be an attractive situation for nuclear power.

(c) Nuclear power looks most favorable in areas in which other fuel resources are exhausted or are basically costly to provide and which, at the same time, require reasonably large sized plants having power requirements that warrant operation of the plant a large fraction of the time. Thus, the first applications of nuclear power may properly be in the more highly industrialized areas of so-called "less developed" countries.

(d) Nuclear power, because of its minimum requirements for logistic support, may permit economically favorable development of natural resources in areas without established extensive transportation networks or with environmental impediments. This is particularly true if the situation is such that extensive transportation networks can be avoided by on site processing.

(e) Nuclear power and the potential hazards of radiation associated with it will undoubtedly require special attention to the establishment of national policy and legislation, and to the education of the public in order to obtain public understanding and acceptance. The effects of potential hazards in terms of national policies and public liability may not be susceptible to adequate treatment in an economic evaluation.

(f) The relative requirements of different power systems for foreign exchange can be more important in the final choice than would be evidenced by economic evaluations based on normal currency exchange rates.

22. The probable impact of nuclear power on foreign exchange requirements merits further discussion. Consider, for example, an area in which it appears that installation of a million kilowatts may be justified in the 1970's. This situation could be applicable to many of the currently less developed countries because of the large expansion in power generating capacity which may be anticipated. Present cost estimates indicate that if this capacity of one million kilowatts was installed in units of 50-150 MWE, each choice of nuclear plants, based on current experience in the United States, would result in an increase in capital cost of approximately 100 million dollars.

23. It is not likely, of course, that the total incremental cost would require foreign currency. The actual amount required would be subject to detailed negotiations

between the buyer and the seller. It seems reasonable, however, based on experience to date, to expect that less than half of the incremental cost would require foreign exchange except for a country which has little or no industrial capability in which case, up to three-fourths of the incremental cost would require foreign exchange. For each mill/kwh saved in fuel cost, the nuclear plants would yield a saving of about 5 million dollars per year. Savings of 2 or 3 mills/kwh in fuel cycle costs seem quite possible. If all fuel (fossil or nuclear) would have to be imported into the area, fuel savings from the nuclear plant could yield reductions in foreign exchange requirements of perhaps as much as 15 million dollars per year.

24. In addition, there is the possibility of developing an industrial capability to perform some of the nuclear fuel cycle operations, thus further reducing foreign exchange requirements. The greatest potential in this area is for eventual development of fuel preparation and fabrication of fuel elements. This part of the fuel cycle could correspond to about 1 mill/kwh, or another 5 million dollars annually for the million KW installed capacity assumed. The prospects for local reprocessing of irradiated fuel at this level of capacity (corresponding to less than 100 tons per year of spent fuel from reactors fueled with slightly enriched uranium) does not look promising. Similarly, the U-235 enrichment capacity required probably would be too small to be economically attractive. It is very likely, however, that reprocessing services for irradiated fuel will be available in countries with larger nuclear power installations, also fuel enriching services will be available on a toll basis, so that full advantage can be taken of purchasing natural uranium on a competitive market. Also, by the 1970s technology is expected to make economically practical the use of plutonium[17] produced in the reactor to minimize the requirements for separative work for U-235 enrichment.

25. It is possible, of course, to defer the need for enriching uranium and reprocessing irradiated fuel by using power reactor concepts which will operate on natural uranium. There is no question but that such plants can be built and can be made to operate reliably and dependably. Again, it should be possible to make the choice primarily on the basis of comparative economics. Capital costs for nuclear plants using reactors designed to operate on natural uranium are relatively more sensitive to the plant capacity than other nuclear power plant systems. This is shown in Figure III, which gives the effect of size upon the unit capital cost for the D_2O-natural uranium and the H_2O-slightly enriched uranium plants based upon best available estimates for plants which could be built today.[18,19,20]

26. The higher unit capital costs for the D_2O-natural uranium plants given in Figure III can be explained by (a) the high investment in D_2O required, (b) the need for somewhat larger cores for natural uranium reactors, and hence larger investment in reactor plant, for the same power output, and (c) the stage of development of the two concepts. While the capital cost differential may approach zero in very large plants (probably above 500 MWE) as more construction experience is obtained in building D_2O plants, at the present there appears to be a capital cost differential (exclusive of heavy water) of about $160/KWE in sizes of the order of 100 MWE. The cost of heavy water at the current price of $61.60/Kg will add approximately $80/KW - this generally will increase the seriousness of any foreign exchange problem. The net effect of these capital cost differentials depends upon the fixed charge rate used, plant capacity factor, and various other factors. Even under low fixed charge rates, often associated with public financing, these capital cost differentials are equivalent to above 2 mills/kwh. Rates associated with private financing would about double this effect. This incremental cost difference in mills/kwh for the capital and fuel is indicated in Figure IV. For these comparisons heavy water moderated plants are taken as being at least as favorable economically as other natural uranium fueled plants. Graphite moderated systems avoid the cost of heavy water but are physically larger and reactivity limitations shorten the fuel irradiation cycle, tending to increase fuel costs.

27. Fuel cycle costs for all reactors increase with decreasing size because of neutron leakage, which results in relatively short fuel exposures for natural uranium fueled plants and relatively higher enrichments for reactors which take advantage of fuel enrichment. The estimated fuel cost as a function of plant size for the D_2O-natural and H_2O-enriched plants is also given in Figure IV.

28. The residual value of the fuel discharged from enriched uranium reactors is considerably higher than the cost of the shipment to a processing facility and the processing charges. In this respect it should be noted that, for a shipping charge of $15/KgU and a processing charge of $30/KgU, the contribution of these charges to the generating cost is less than 0.5 mill/kwh because of the high burnup of fuel (15MWD/KgU) which can be achieved in reactors using slightly enriched fuel. While there may be somewhat higher shipping charges for return of fuel from, for example, a country several thousand miles from the processing facility, this incremental cost would not be expected to increase the generating cost more than 0.1 mill/kwh over cost estimates based upon shipment within the United States. In the case of natural uranium reactors, shipping and processing charges for these distances would be expected to exceed the fuel value of the discharged nuclear fuel. Here, the discharged fuel could be stored until a more economically favorable situation developed as regards fuel processing or value of plutonium in the spent fuel.

29. The costs which have been presented in this paper refer in most part to costs in the United States. Specific estimates would be required in order to determine what the costs would be in specific less-developed nations. In general, in spite of the possible lower wages in the less-developed countries, it is to be expected that there will be off-setting costs for skilled foreign technicians, training and organization of domestic skills, and transport of plant components, so that the cost of installing a nuclear plant in a less-developed country will be higher than for the United States. The situation is the same for a conventional fossil fueled station.

30. The United States will continue to give wide dissemination to information developed in its extensive nuclear power program and will endeavor to provide such other assistance as may be helpful in arriving at a sound conclusion on the merits of nuclear power in specific countries.

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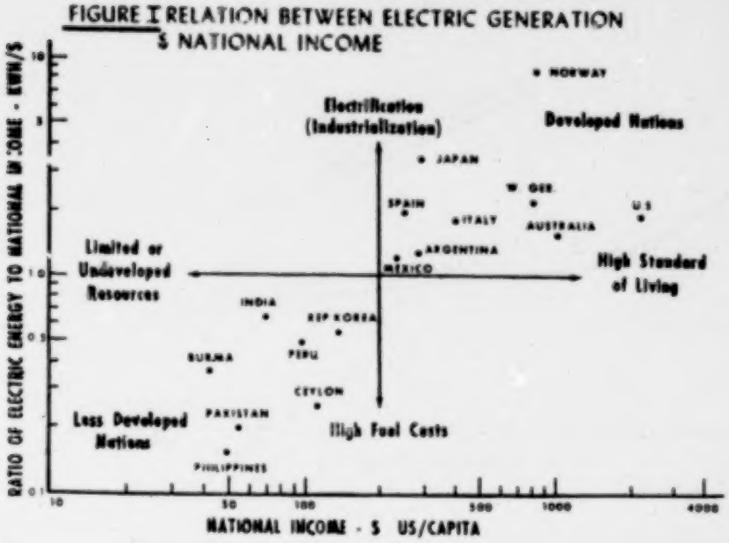

FIGURE I RELATION BETWEEN ELECTRIC GENERATION & NATIONAL INCOME

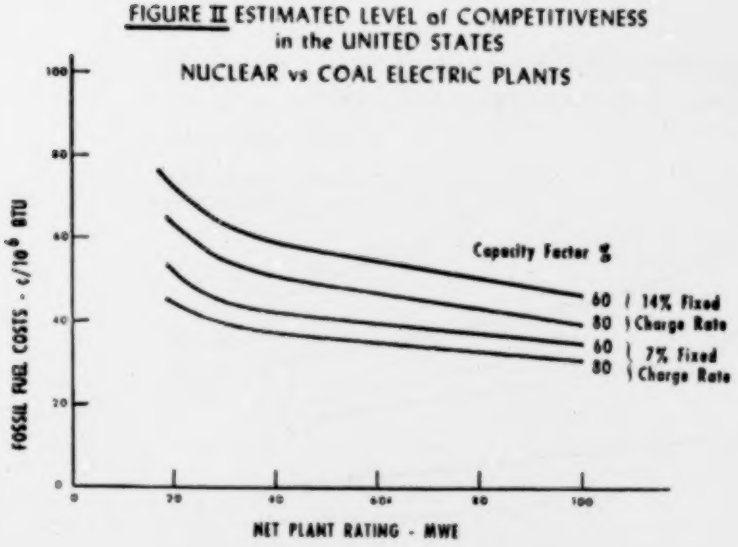
FIGURE II ESTIMATED LEVEL of COMPETITIVENESS
in the UNITED STATES
NUCLEAR vs COAL ELECTRIC PLANTS
FOSSIL FUEL COSTS - ¢/10⁶ BTU
Capacity Factor %
60 } 14% Fixed
80 } Charge Rate
60 } 7% Fixed
80 } Charge Rate
NET PLANT RATING - MWE

FIGURE II ESTIMATED LEVEL OF COMPETITIVENESS
IN THE UNITED STATES
NUCLEAR vs COAL ELECTRIC PLANTS

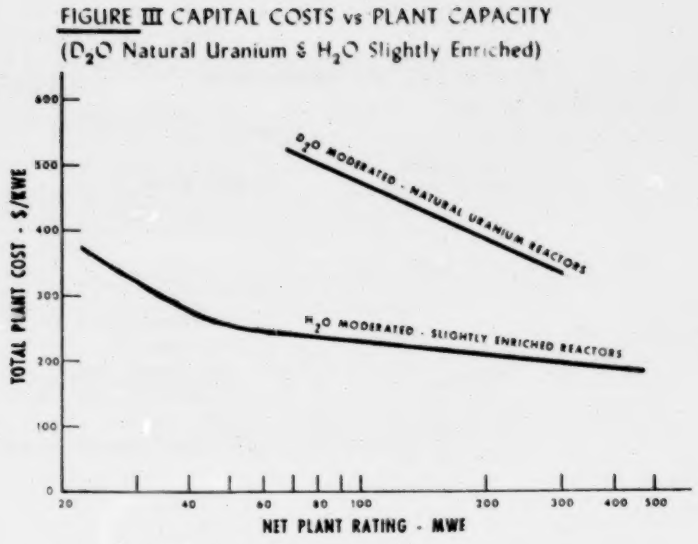

FIGURE III CAPITAL COSTS vs PLANT CAPACITY
(D_2O Natural Uranium & H_2O Slightly Enriched)

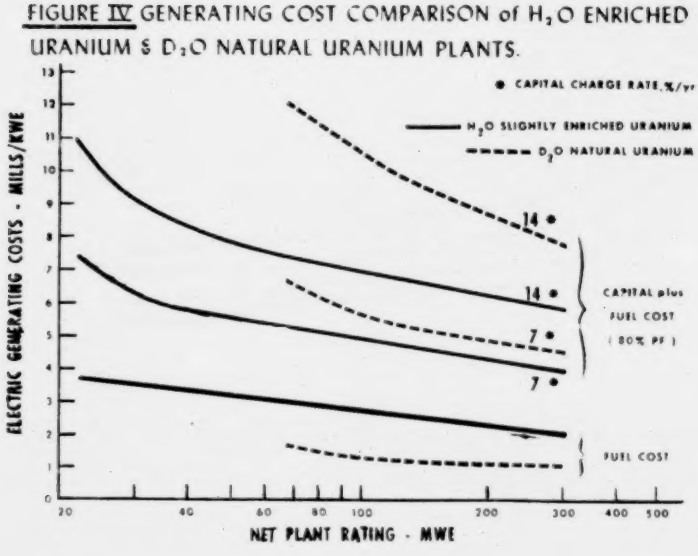

FIGURE IV GENERATING COST COMPARISON OF H_2O ENRICHED URANIUM & D_2O NATURAL URANIUM PLANTS

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CONFÉRENCE DES NATIONS UNIES
SUR L'APPLICATION DE LA SCIENCE ET DE LA TECHNIQUE
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Point de l'ordre du jour : A. 4. 2. 2

Commission Economique pour l'Europe
des Nations Unies

AMELIORATION
DES COMBUSTIBLES COMMERCIAUX

Par la Commission Economique pour l'Europe
des Nations Unies

Les mémoires rédigés à l'intention de la Conférence des Nations Unies sur l'application de la science et de la technique dans l'intérêt des régions peu développées sont des documents de travail. Ils sont publiés tels qu'ils ont été présentés et les assertions et opinions qu'ils contiennent sont celles de leurs auteurs.

NOTES

1. Les mémoires choisis pour être présentés en séance générale pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

2. Les mémoires choisis pour être présentés en séance spéciale pourront être obtenus à la Conférence dans l'une seulement de ces langues officielles.

3. Les résumés qui ont été rédigés pour tous les mémoires par les auteurs de ceux-ci pourront être obtenus à la Conférence dans les langues officielles suivantes des Nations Unies: anglais, espagnol, français et russe.

4. Préalablement à la Conférence, les mémoires et les résumés ne feront pas l'objet d'une distribution générale mais d'un tirage restreint destiné aux délégations des gouvernements et autres participants officiels. La publication et la distribution générale des actes de la Conférence s'effectueront conformément aux règles et pratiques agréées par le Comité des publications des Nations Unies.

AMELIORATION DES COMBUSTIBLES COMMERCIAUX

Commission économique pour l'Europe
des Nations Unies

1. La valorisation des combustibles est un problème très complexe qui englobe un nombre considérable de domaines scientifiques et techniques. De nombreux instituts et laboratoires scientifiques s'occupent de toutes ces questions. Il semble qu'un examen des méthodes élaborées jusqu'à ce jour permet d'en faire ressortir quelques-unes qui soient d'un intérêt tout particulier pour les régions ne disposant pas de ressources suffisantes. L'intérêt de ces méthodes réside dans la possibilité d'obtenir un produit adaptable le plus économiquement possible à une utilisation finale essentielle. Quelques-unes de ces méthodes sont les suivantes :

I Préparation du charbon
II Utilisation rationnelle du charbon pour la cokéfaction
III Carbonisation à basse et moyenne température
IV Utilisation rationnelle des combustibles solides à fort pourcentage de stériles ou de fines en combustion industrielle.

2. Les deux premiers points présentent une importance toute particulière pour les régions en voie de développement, qui en premier lieu seront intéressées par les charbons destinés à la cokéfaction et les moyens de valoriser à cette fin les combustibles solides produits localement. Cette étude portera donc principalement sur ces deux sujets.

I. Préparation du charbon

(a) Méthodes de préparation utilisées dans divers pays

Différents procédés sont utilisés : bacs à pulsation, couloir, milieu dense, flottation, cyclones, triage à main, tables d'épuration etc. L'utilisation d'un procédé particulier est conditionné par de nombreux facteurs relevant en premier lieu des caractéristiques naturelles du charbon (cendres, dimension des grains, teneur en humidité, etc.) et de son utilisation finale : cokeries, chaufferies, centrales électriques et autres.

(b) Evolution

En général, les mines exploitant un charbon dont la qualité se détériore sans cesse: conditions géologiques plus difficiles et mécanisation des travaux d'exploitation. Cette détérioration se manifeste par une teneur en cendres sensiblement plus élevée et une dimension plus petite du tout venant.

(i) Préparation partielle au fond

Ce procédé permet d'augmenter l'efficacité du transport et d'accroître le rendement des installations de préparation à la surface. En général, ce procédé repose sur le triage manuel.

(ii) Traitement des gros charbons

La difficulté de recruter la main-d'oeuvre dans les pays industrialisés a été une des principales raisons de l'application du traitement mécanique. Dans la plupart des cas, un concassage précède ou suit la préparation mécanique des gros charbons qui s'effectue au moyen du lavage par liquide dense.

(iii) Lavage des grains

Il y a une tendance très nette vers la généralisation de l'utilisation des appareils à liquide dense aux dépens des rhéolaveurs, des tables de traitement à sec et des bacs à pulsation.

(iv) Lavage des fines

Les appareils de pistonnage ont été très perfectionnés. On note également l'utilisation des "tables d'épuration par voie humide" et du cyclone-laveur.

(v) Traitement des eaux

Les méthodes en application sont la flottation (charbon à coke), la filtration, le séchage thermique, les décanteurs.

(c) Préparation du charbon destiné à la cokéfaction

La construction d'un atelier de préparation avec lavoir est une entreprise très coûteuse. Il est donc très important pour les régions ne disposant pas suffisamment de capitaux d'en faire l'usage le plus rationnel. La priorité de construction d'un atelier de préparation doit être accordée aux charbons destinés à la cokéfaction au détriment des autres qualités de charbon, car la production du coke exige des charbons à faible teneur en cendres. Une revue des procédés de lavage de charbons destinés à la cokéfaction, dans un certain nombre de pays, donnera la possibilité de faire une appréciation comparative des méthodes en vigueur.

(i) FRANCE

a. Méthodes de lavage utilisées pour l'enrichissement du charbon destiné à la carbonisation

Les grains de ϕ 6, ϕ 8 ou 10 mm sont lavés par :

- bac à piston
- rhéolaveur
- milieu dense

Les fines 0,5 - 6, 05 - 8 ou 0,5 - 10 mm sont traitées par :

- bac à lit filtrant
- rhéclaveur

Les schlamms sont traités par flottation.

b. Importance relative de chacune des méthodes utilisées :

Il n'existe pas de statistiques par qualité de charbon.
Pour l'ensemble des qualités (cokéfiants ou non), les chiffres sont les suivants (année 1959) - grains + fines + schlamms :

- bacs à piston ..... 51,1 %
- rhéolaveurs ..... 5,3 %
- appareils à liquide dense ..... 32,6 %
- flottation ..... 6,6 %
- épuration pneumatique ..... 3,2 %
- méthodes diverses ..... 1,2 %

En outre, on peut préciser que la totalité des schlamms utilisés en carbonisation sont traités par flottation.
Pour les fines, on peut évaluer à 95 % les fines lavées en bac à lit filtrant
à 5 % les fines lavées par rhéolaveur.

Il existe une installation traitant des fines non cokéfiantes par cyclone.

c. Méthode la plus rationnelle

Pour le		6	: milieu dense
" "		0,5-6	: bac à felspath
" "		<0,5	: flottation

(ii) POLOGNE

En Pologne, on utilise les méthodes ci-après :

- tri à la main
- lavage au bac à piston
- lavage par milieu dense
- flottation.

Dans les atelier anciens, on opère le tri à la main pour les charbons d'un calibre de plus de 80 mm; le traitement est mécanique, dans des bacs à piston, pour les calibres de 80 - 0,5 mm; enfin le procédé par flottation est utilisé pour les fines inférieures à 0,5 mm.

Dans les ateliers modernes, on lave les charbons de plus de 80 mm en milieu dense, dans une suspension de magnétite, les menus sont lavés au bac à piston et les fines de moins de 0,5 mm par flottation.

A l'heure actuelle, on élimine le tri à la main, les gros morceaux de charbon sont broyés de façon à donner des morceaux d'un calibre inférieur à 120 mm, après quoi ils sont traités mécaniquement.

Du tonnage total de charbon destiné à la carbonisation, 87,5 % sont lavés au bac à piston, 3,7 % en milieu dense, 5,8 % par flottation, et 3 % traités à la main.

L'expérience acquise en Pologne montre que l'on n'a encore trouvé aucune méthode qui puisse être qualifiée de meilleure et qui soit appliquée à l'exclusion des autres. Pour choisir une méthode de préparation mécanique, il faut toujours tenir compte des caractéristiques du charbon. Beaucoup de charbons à coke polonais présentent des caractéristiques favorables au lavage, si bien que la méthode la plus commune est le lavage au bac à piston, avec pulsation pneumatique et régulation automatique. Lorsque la machine est bien conçue (longueur de la course, nombre de tours, etc.), les résultats obtenus sont satisfaisants. Dans certains cas, on obtient de 4,0 % à 5,0 % de cendre, et dans les déchets la perte de charbon est insignifiante (inférieure à 1 %).

Comme les charbons polonais sont faciles à laver, les procédés de lavage en milieu dense ne sont pas toujours économiques; pourtant, il est à signaler que l'on construit actuellement 5 ateliers qui seront équipés de séparateurs par milieu dense pour les charbons de plus de 10 mm, ainsi qu'un atelier à hydro-cyclone pour le lavage secondaire des mixtes de 10 - 0 mm obtenus à partir de charbons présentant de "mauvaises" caractéristiques au lavage.

(iii) ROYAUME-UNI

On utilise le lavage au bac à piston, le milieu dense et la flottation. Le lavage au bac à piston est la méthode la plus largement employée parce que beaucoup des ateliers existants ont été installés avant que la méthode de lavage par milieu dense ait été mise au point pour les menus. Dans les ateliers de construction récente, on utilise largement le lavage par milieu dense. L'on traite actuellement au bac à piston 70 % du charbon destiné à la carbonisation, en milieu dense de 20 à 25 % et par flottation de 8 à 10 %. Le choix de la méthode dépend pour beaucoup du type et du calibre du charbon à traiter. Si un charbon présente de "bonnes" caractéristiques au lavage, le bac à piston est efficace; s'il présente de "mauvaises" caractéristiques de lavage, les méthodes de lavage en milieu dense sont plus efficaces. L'on utilise la flottation pour le lavage des fines d'une granulométrie inférieure à 0,5 mm et c'est la seule méthode efficace pour les fines.

(iv) ETATS-UNIS D'AMERIQUE

Les statistiques de la préparation mécanique des charbons bitumeux et du lignite établies par type d'équipement, ne sont pas ventilées par utilisation. En 1960, l'on a épuré mécaniquement, 273 169 000 tonnes de charbon, soit 65,7 % de la production totale. Sur le total épuré mécaniquement, 50 % ont été lavés dans des bacs à piston; 11,3 % au moyen de tables; 4,0 % au moyen de classificateurs; 2,8 % dans des lavoirs; 24,3 % en milieu dense; 0,7 % par flottation; 6,6 % par épuration pneumatique et 0,3 % dans un équipement non classé. Le choix de la méthode d'épuration mécanique dépend en grande partie des caractéristiques du charbon. Beaucoup des charbons à coke des Etats-Unis posent un grave problème de lavage: la réduction du soufre. Lorsqu'il faut choisir un procédé de séparation à faible densité pour obtenir un produit lavé satisfaisant du point de vue chimique, on lave d'ordinaire en milieu dense les gros grains (plus de 6 mm) et au moyen de tables les fines (moins de 6 mm). On utilise toutes sortes d'équipements pour épurer les charbons à cokéfier.

II. Utilisation rationnelle du charbon pour la cokéfaction

Le coke est l'un des produits essentiels nécessaire à la production de la fonte, tout pays envisageant la construction ou le développement de son industrie lourde sera confronté avec le problème de ravitaillement en coke métallurgique. Ce problème sera lié directement à l'utilisation la plus efficace possible de qualités de charbon disponibles, en vue de la production de coke. Le perfectionnement des méthodes, aussi bien de préparation des pâtes à coke que de la carbonisation, a permis d'élargir dans une mesure considérable la gamme des charbons susceptibles d'être utilisés pour la fabrication du coke. Il ne faut pas perdre de vue que les conditions économiques sont très variables d'un pays à l'autre et le choix de méthodes pour la composition et la préparation des pâtes à coke, de même que pour la carbonisation, ne peut être recommandé qu'en fonction des impératifs économiques particuliers des pays intéressés. Il est essentiel que, dans toute la mesure du possible, la totalité des charbons à coke soit réservée à la production de coke et du gaz, et que, toutes les fois que cela est possible, ce matériau précieux ne soit admis que comme un constituant d'un mélange comportant des charbons moins facilement cokéfiables.

(a) Classification internationale des houilles par nature

Le Comité du charbon de la Commission économique pour l'Europe a élaboré un système de classification internationale des houilles par nature et un système de groupement statistique des houilles. A sa trente-septième session, tenue en mars 1956, le Comité du charbon, considérant les bons résultats qu'ont donnés aux essais ces deux systèmes, a recommandé aux gouvernements de mettre les deux systèmes en application pratique.

i) Définition de la classification internationale

Au sens de la classification internationale, les houilles sont des charbons possédant, sur échantillon humide, exempt de cendres, un pouvoir calorifique brut supérieur à 5 700 kcal/kg. On entend par l'expression "classification par nature" la différenciation des charbons d'après l'ensemble de leurs propriétés physico-chimiques. Les différences de nature entre un charbon et un autre sont considérées comme résultant de différences entre le degré de carbonification dans la série naturelle allant de la tourbe à l'anthracite. La "nature" d'un charbon ne dépend pas de ses caractéristiques accessoires ni des impuretés qu'il contient (teneur en matières minérales, composition et point de fusion des cendres, teneur en soufre, etc.). La classification s'applique aux houilles de toutes les périodes géologiques.

a. Répartition des charbons en classes

Les charbons sont d'abord classés suivant l'indice des matières volatiles du produit sec exempt de cendres. Les charbons dont l'indice des matières volatiles dépasse 33 %, c'est-à-dire la majeure partie des charbons du monde, sont en outre subdivisés en fonction de leur pouvoir calorifique supérieur, calculé sur le produit humide, exempt de cendres.

b. Subdivision des classes en groupes

Après avoir été répartis dans les classes, les charbons sont subdivisés en groupes en fonction de leur pouvoir agglutinant; ce terme, pris au sens large, traduit le comportement du charbon lorsqu'il est chauffé rapidement, par exemple en cas de combustion. Le pouvoir agglutinant peut être exprimé soit par l'indice de gonflement au creuset, soit par l'indice Roga.

c. Subdivision des groupes en sous-groupes

Après répartition dans les groupes, les charbons sont subdivisés en sous-groupes en fonction de leur pouvoir cokéfiant; ce terme, pris au sens large, traduit le comportement du charbon lorsqu'il est chauffé lentement, par exemple, en cas de carbonisation. Le pouvoir cokéfiant du charbon peut être exprimé soit par la dilatation maximale, soit par le type de coke Gray-King.

ii) Groupement statistique des houilles

Dans ce système, les sous-groupes établis conformément à la classification internationale des houilles par nature ont été réunis en un nombre relativement peu élevé de groupes statistiques désignés par les chiffres romains de I à VII.

L'établissement d'une classification internationale du charbon a facilité énormément la compréhension et les études comparatives des divers procédés utilisés dans de nombreux pays.

(b) Composition et préparation des mélanges

D'une manière générale, on utilise à l'heure actuelle aux fins de la carbonisation d'importants tonnages de charbon autres que les charbons à coke proprement dits. Les exemples suivants montrent les différentes méthodes utilisées :

i) FRANCE

Les cokeries qui ne peuvent disposer que de charbons des classes VD ou VI ont dû trouver le moyen de triompher des difficultés résultant du faible pouvoir cokéfiant de ces charbons.

Les analyses de laboratoire à l'effet de déterminer les propriétés cokéfiantes portent en général sur la teneur en matières volatiles (MV), l'indice de

gonflement AFNOR, les mesures au dilatomètre et, plus rarement au plasto-mètre.

Les mélanges dont on se sert actuellement dans le bassin du Nord-Pas-de-Calais et dans les charbonnages de Lorraine sont l'aboutissement, de longues analyses de laboratoire pour rechercher ceux des charbons locaux qui sont les plus aptes, et d'expériences à l'échelle industrielle dans les cokeries, pour choisir le charbon d'appoint et déterminer les meilleures conditions de préparation, d'enfournement et de cuisson. Dans les deux cas, on utilise des mélanges ternaires composés du charbon gras local le plus fusible et le moins riche en MV, d'un charbon à coke proprement dit et d'un amaigrissant (poussier de coke finement pulvérisé, semi-coke ou charbon demi-gras légèrement fusible). La teneur moyenne en MV de ce type de mélange est de l'ordre de 28 à 29 %.

La préparation de la charge demande un calibrage approprié et très précis (80 à 85 % d'éléments inférieurs à 2 mm) - parfois avec broyage séparé de l'amaigrissant, et un mélange.

On augmente la densité de l'enfournement soit par huilage (enfournement répalé), soit par pilonnage (charge humide ou charge sèche), et la cuisson s'effectue à haute température (1275 à 1320° C dans les piédroits).

C'est en Lorraine que le problème de l'utilisation la plus complète possible des charbons locaux, généralement impropres à la fabrication de coke métallurgique, a été le plus difficile à résoudre. Les solutions adoptées présentent un intérêt général.

ii) POLOGNE

Le pouvoir agglutinant des mélanges représentatifs correspond à un indice Roga de 46 à 58 et leur teneur en MV varie entre 29 et 32 %. On veille particulièrement à l'homogénéité de la qualité des charbons fournis sous le rapport de la teneur en cendres, de la teneur en eau et du pouvoir agglutinant.

En gros, les charbons utilisés par l'industrie de la carbonisation se répartissent entre les classes V et VI, avec un faible pourcentage pour la classe IV.

Il appartient à chaque usine de doser ses charges à partir de ces charbons en fonction de la qualité de coke désirée. Les proportions suivantes peuvent être données comme celles d'un mélange-type destiné à la production de coke métallurgique :

	%
Classe VI A	18
V C et V D	61
V B	7
IV	14

On pratique régulièrement un calibrage soigneux (pour le coke de première qualité, 95 % au moins du charbon doit être inférieur à 3 mm, proportion optima de grains de cette dimension 96-97 %; pour le coke de deuxième qualité, 90 %). Le broyage et le mélange portent à la fois sur les charbons constituants et sur la charge avant enfournement. Le contrôle de la teneur en eau et le pilonnage de la charge (dehsité 1050 kg/m^3) sont de pratique courante.

Les examens en laboratoire comportent :

- la détermination continue des teneurs en eau et en matières volatiles et celle de l'indice Roga;
- périodiquement l'examen de la plasticité par la méthode Sapojnikov et de la pression de gonflement par la méthode Korten-Damm.

En ce qui concerne la prédétermination des proportions optima d'un mélange de charbons, celles-ci sont basées à la fois sur la teneur en matières volatiles et sur les résultats de l'essai Sapojnikov qui est pratique courante dans ce pays.

Outre cet examen, des mélanges prédéterminés comme il est indiqué ci-dessus sont essayés à la cokéfaction dans un four-pilote.

D'importants travaux ont été effectués en vue de caractériser les charbons polonais du point de vue de leur pouvoir cokéfiant par la méthode plastométrique de Sapojnikov et Basilevitch. Ces travaux ont contribué à définir dans leurs grandes lignes les classes de charbons polonais qui peuvent entrer dans la constitution de la pâte pour donner un coke de qualité satisfaisante.

En ce qui concerne l'avenir de la technique de la carbonisation en vue de la production de coke métallurgique, on pense en Pologne que de sensibles progrès dans ce domaine pourront résulter :

- d'une extension de la technique du broyage sélectif eu égard aux constituants pétrographiques des charbons;
- d'une extension de la technique du pilonnage de la charge en vue d'accroître sa densité;
- d'une cuisson plus rapide.

iii) UNION DES REPUBLIQUES SOCIALISTES SOVIETIQUES

La pratique des mélanges a sa source dans la nécessité de triompher des inconvénients présentés par les charbons locaux, qui sont fortement gonflants, dans les cokeries du Donetz et de la région du Dniepr.

Généralement, lorsqu'une charge destinée à la cokéfaction est constituée par un mélange, les charbons constituants appartiennent à quatre classes différant entre-elles du fait des teneurs en matières volatiles et des indices plastométriques : contraction, épaisseur de la couche plastique.

L'emploi généralisé, dans l'industrie, de la méthode plastométrique, en vue de déterminer le pouvoir cokéfiant des charbons extraits et de les classifier d'après cette propriété a permis d'acquérir une large expérience. Grâce à cette classification il est devenu possible de déterminer à l'avance les proportions nécessaires pour former de bons mélanges à coke. Depuis la guerre, cette méthode a été aussi appliquée, avec succès, à divers charbons étrangers.

Une recherche poussée et ininterrompue en matière de détermination du pouvoir cokéfiant des charbons a conduit à l'établissement d'une théorie générale de la cokéfaction.

Des recherches sont en cours portant sur les méthodes d'examen suivantes : essai Roga, essai au dilatomètre, essai Gray-King, proportions des constituants pétrographiques.

De plus, on attache une attention particulière au rendement thermique de l'opération et si des rendements de 92 % sont couramment signalés, on espère amener ce pourcentage à 98 par des améliorations portant sur le refroidissement à sec. Le refroidissement du coke à sec est considéré dorénavant comme devant être un élément essentiel de toute installation de carbonisation de quelque importance. De l'étude effectuée et de l'expérience acquise à ce sujet dans ce pays, on a déduit que ce dispositif d'extinction peut être amorti en trois ans, sur les bases suivantes :

- Capacité par chambre de refroidissement : 240 m^3, 40 tonnes par jour;
- Temps pris pour le refroidissement : environ 3 heures;

Couplage de chaque chambre de refroidissement à une chaudière produisant de la vapeur de 18 à 30 atmosphères et à 375°C;

- Production de vapeur par tonne de coke : 350 kg.

Ceci doit être ajouté à certains avantages résultant d'une amélioration des qualités du coke ainsi obtenu.

iv) ROYAUME-UNI

De la technique des mélanges telle qu'elle est pratiquée au Royaume-Uni, il est difficile de dégager des principes généraux, car les conditions dans lesquelles s'effectuent ces mélanges dépendent dans une mesure appréciable du transport de quantités relativement faibles de charbon d'appoint vers les régions où le charbon local ne peut donner seul la qualité de coke désirée. C'est pour cette raison que le mélange de charbons très volatils et de charbons faiblement volatils, courant parce qu'économiquement possible dans d'autres pays, n'est qu'exceptionnellement pratiquée au Royaume-Uni. Ces mélanges sont caractérisés par une teneur en matières volatiles relativement forte, sauf lorsqu'on dispose de charbons de la classe VB; on remédie aux pressions de gonflement excessives éventuelles par des mélanges de charbons à teneur élevée en matières volatiles fortement ou moyennement agglutinants.

Les analyses de carbonisation couramment faites en laboratoire sont les suivantes : indice de gonflement (British Standard), essai d'agglutination (British Standard), et essai Gray-King. On a en outre recours à l'essai de gonflement Koppers, à l'essai Nedelmann lorsque l'on soupçonne une pression de gonflement excessive et à l'essai dilatométrique. Aucun des essais précités n'est cependant considéré comme suffisant en soi pour définir ce comportement mais comme les livraisons de charbon sont habituellement assez homogènes d'un arrivage à l'autre, on considère fréquemment en raison de leur bonne reproductibilité et de leur commodité, que de simples paramètres comme la teneur en matières volatiles du mélange et l'indice de gonflement (B.S) suffisent.

On attache une attention de plus en plus grande à la préparation de la charge par le contrôle des constituants pétrographiques, le pré-traitement du charbon, et l'incorporation au charbon de matières diverses.

L'influence que peuvent avoir des variations de la charge portant sur la teneur en humidité, l'adjonction d'huile, le calibrage et la nature des charbons enfournés est particulièrement étudiée. Un des premiers objectifs de cette étude est la détermination des facteurs qui agissent sur la densité de la charge, dont l'influence sur la qualité du coke produit est d'une importance évidente. Dans cet ordre d'idée et en priorité, c'est la constance de la qualité du coke produit à partir de charbons divers qui retient l'attention plus que la recherche de la perfection dans cette qualité.

Pour ce qui est des méthodes de la préparation de la charge, on pratique le calibrage minutieux des constituants de la pâte, mais non par des opérations séparées, et un mélange poussé. Habituellement, on amène le produit par broyage au calibre de 1/8 de pouce avec 10 à 20 % de refus; toutefois, on ne pilonne presque plus la charge. On veille pourtant à l'uniformité de sa densité et l'on y ajoute parfois un faible pourcentage d'huile lourde pour empêcher des fluctuations adventices de cette densité.

(c) Méthodes d'analyse en laboratoire pour la sélection des charbons en vue de la fabrication du coke

Deux propriétés présentent une importance primordiale pour la connaissance du comportement des charbons :-la plasticité et la contraction finale. Toute appréciation quantitative de ces propriétés, à condition que la reproductibilité des

essais soit suffisante, devrait conduire à une évaluation du comportement des mélanges. Ainsi, par exemple, on utilise dans certains cas la méthode plastométrique. Cette méthode repose sur une théorie relative à la nature chimique de l'agglutination. L'agglutinabilité d'un charbon peut être définie comme la mesure dans laquelle les bitumes fondus qui apparaissent dans la première phase de la carbonisation (200°C à 500°C) dissolvent les autres éléments non fondus, et elle est proportionnelle au temps qui s'écoule entre la dissolution et le commencement du durcissement (en général à partir de 500°C ou plus) qui lui-même est un signe de décomposition.

En d'autres termes, l'agglutinabilité d'un charbon est son aptitude à produire un semi-coke de structure homogène, et cette aptitude doit être proportionnelle au temps pendant lequel le charbon fondu reste plastique, c'est-à-dire à l'épaisseur de la couche plastique. Sur cette base, Sapojnikov a admis que le pouvoir agglutinant d'un charbon donné était proportionnel à l'épaisseur de la couche plastique, et c'est l'épaisseur maximale de cette couche plastique qu'il a choisie comme paramètre pour mesurer le pouvoir agglutinant d'une houille donnée. Il s'agit ici de la première phase du processus de la carbonisation : la production d'un semi-coke cohérent et homogène.

La fabrication d'un coke de haute température satisfaisant dépend du comportement de ce semi-coke dans la deuxième phase, c'est-à-dire au moment où se produisent simultanément l'hydrogénation et le durcissement du charbon plastifié. On a constaté que ce comportement varie suivant que les produits gazeux résultant de la décomposition de la couche plastique sont libérés par le côté chaud ou par le côté froid du chargement. A son tour, ce comportement dépend, pour une carbonisation à pression constante, de la contraction finale de la charge.

En partant de ces considérations, Sapojnikov a pris comme paramètres pour mesurer les propriétés cokéfiantes d'un charbon donné :

- l'épaisseur maximale de la couche plastique;
- la contraction axiale mesurée par l'abaissement final de la courbe de gonflement.

(d) Quelques méthodes spéciales de cuisson des mélanges

C'est dans le bassin français de Lorraine que les efforts en vue de surmonter les difficultés éprouvées en matière de cokéfaction de charbons locaux généralement impropres à la cokéfaction lorsqu'ils sont enfournés seuls ou sans une préparation spéciale de la charge, ont été les plus grands, par leur ampleur et leur diversité.

La plupart des méthodes expérimentées dans d'autres pays, concernant tel ou tel aspect de la carbonisation, ont également été mises à l'essai en Lorraine, et c'est ce qui rend l'expérience acquise dans ce bassin d'un si grand intérêt pour les autres.

En Sarre, on a également recueilli en la matière des renseignements d'un ordre très voisin; en effet, les problèmes de cokéfaction y sont dans une certaine mesure analogues, quoique moins aigus, en raison de la prédominance de bas fourneaux que l'on peut approvisionner en cokes d'une résistance légèrement inférieure à celle du coke métallurgique proprement dit.

D'après le système international de classification, les charbons lorrains appartiennent essentiellement aux classes suivantes : 632, 633, 711 et, pour un faible tonnage, 721 et 722; dans les conditions ordinaires de traitement, ces charbons, lorsqu'ils sont cokéfiés, fondent faiblement à une température excessivement basse et dans des limites de température trop étroites, si bien que la masse se contracte trop rapidement après solidification.

Dans ces conditions, pour utiliser le plus complètement possible les charbons lorrains, il a été nécessaire de mettre au point des méthodes spéciales de

cokéfaction qui, tout en étant rentables, puissent aussi être appliquées rapidement dans les cokeries existantes sans exiger de coûteuses transformations.

i) Principes

Ces procédés reposent sur quatre idées essentielles : augmentation de la densité du chargement, incorporation d'un amaigrissant, adjonction d'un charbon fusible et adaptation de la préparation des pâtes aux propriétés des constituants pétrographiques des charbons.

a. - Augmentation de la densité du chargement

Comme les charbons lorrains sont faiblement gonflants et moins fusibles que d'autres, il faut, quand on les incorpore dans une forte proportion à une pâte, réduire dans une mesure appropriée le volume des vides interstitiels de façon que le contact entre les particules de charbon soit accru et leur fusion en une masse homogène améliorée.

On y parvient par l'augmentation de la densité du chargement et par une distribution appropriée des différentes granulométries sans augmenter exagérément la proportion d'éléments fins. Un broyage méthodique, un tamisage avant le passage au broyeur et des mélanges soigneux sont nécessaires pour réalis r cette dernière condition; quant à l'augmentation de la densité, elle est réalisée par pilonnage du chargement ou par séchage avant enfournement.

b. - Incorporation d'un amaigrissant

En incorporant à la pâte un amaigrissant - charbon maigre, semi-coke ou poussier de coke - on diminue la fissuration du coke. Le phénomène n'est d'ailleurs pas encore entièrement compris mais on pense que ce procédé donne à la masse une meilleure résistance aux tensions provoquées par la contraction.

c. - Adjonction d'un charbon fusible

Pour pouvoir augmenter la proportion d'amaigrissant à incorporer dans un mélange, il s'est parfois révélé utile d'y ajouter un constituant supplémentaire sous forme de charbon très fusible ayant un pouvoir agglutinant élevé. On a été amené à agir de cette façon du fait du faible pouvoir agglutinant des charbons lorrains et, en pareil cas, on a dû incorporer à la pâte des charbons des classes 434 et 435 provenant d'autres bassins charbonniers.

d. - Adaptation de la préparation des pâtes aux propriétés des constituants pétrographiques des charbons

Les constituants pétrographiques d'un charbon quel qu'il soit (fusain, vitrain, clarain et durain) présentent des aptitudes à la cokéfaction très différentes qui augmentent avec la dureté ou la résistance à l'écrasement. Pourtant ces propriétés peuvent varier d'un charbon à un autre. Par un broyage et un tamisage sélectifs, on réduit les constituants les moins fusibles à une granulométrie plus fine que les constituants les plus fusibles. Par ce moyen on utilise au maximum les éléments les plus fusibles et on réalise l'homogénéité et une plus forte densité du chargement, condition préalable de la fabrication d'un bon coke.

ii) Exemples de l'utilisation de deux de ces principes en Lorraine

a. - Augmentation de la densité de la charge par pilonnage

Selon cette technique, la charge est comprimée avant l'enfournement par des machines pilonneuses qui portent la densité de son niveau normal, soit 700 kg/m^3, à 900 ou 950 kg/m^3 environ, en réduisant à peu près des deux tiers le volume des interstices.

Le contact entre les particules de charbon étant ainsi renforcé par pilonnage, l'agglutination de la masse est favorisée. La température de solidification du charbon à coke utilisé dans ce procédé est élevée et sa teneur en MV est faible, ce qui maintient plus longtemps la masse à l'état plastique. De ce fait, la

contraction des charbons lorrains entrant dans la composition de la pâte - très forte au début - peut avoir lieu alors que la masse est encore à l'état plastique, ce qui réduit la fissuration. Ce résultat est encore favorisé par l'adjonction d'un amaigrissant, rendue possible par le pilonnage, qui abaisse encore la teneur moyenne en MV du mélange, ce qui réduit la tendance de la masse à se fissurer au moment de la solidification. On veille à ce que l'amaigrissant (poussier de coke ou semi-coke) soit finement broyé dans des broyeurs à boulets (90 % < 0,2 mm et 60 % < 0,1 mm) de sorte que la surface des particules devient lisse; la quantité de bitume absorbée est sensiblement réduite et l'adjonction de bon charbon à coke devient inutile dans certaines pâtes.

L'emploi de cette méthode à l'échelle industrielle a révélé que le coke obtenu ne présente pas de variations notables de qualité tant que les proportions des constituants de la pâte sont maintenues à moins de 5 % des chiffres spécifiés.

Du point de vue de la rentabilité du procédé, les indications fournies par la Direction de l'usine de Carling, utilisant cette technique, précisent ce qui suit :

(a) On réalise une économie de 7 % sur l'ensemble des fours, machines et annexes grâce à la plus grande capacité unitaire des fours chargés par pilonnage, et cela en dépit du supplément initial de dépense que représentent les machines enfourneuses et pilonneuses, par rapport à l'équipement de chargement ordinaire.

(b) Les frais d'exploitation ne diffèrent pas sensiblement de ceux des cokeries classiques utilisant des charbons analogues, car la préparation de la pâte exige l'emploi de cinq ouvriers supplémentaires par poste pour un enfournement de 3000 tonnes par jour.

(c) En outre, cette technique permet d'utiliser les charbons locaux ou des types de charbons moins recherchés; on réalise ainsi une économie supplémentaire, variable suivant les circonstances locales.

b. - Augmentation de la densité de la charge par séchage

Cette technique présente ceci de particulier qu'elle peut être appliquée aux fours classiques enfournant leur charge par gravité.

Le séchage du charbon, qui doit être effectué soigneusement pour éviter l'oxydation, porte la densité du chargement à 800 kg/m^3 ou davantage (teneur en eau après séchage : 2 à 3 %) ce qui établit un contact plus étroit entre les particules, augmente le gradient de température au début de l'opération et assure, indirectement, une amélioration de 20 % environ de la productivité des fours.

Outre l'adjonction d'un sécheur, il suffit d'apporter à l'équipement de mélange de chargement des modifications peu coûteuses.

Le séchage à la cokerie de Marienau, qui fait usage de ce procédé, est effectué en quelques secondes dans un courant ascendant de gaz chauds qui ne porte pas la température des charbons séchés à plus de 70°C, toute oxydation importante étant ainsi évitée. Du point de vue de l'oxydation des charbons, il faut surveiller la température à laquelle les charbons sont emmagasinés (les charbons lorrains peuvent se détériorer en quarante-huit heures s'ils sont emmagasinés à plus de 40°C).

L'inclusion dans la pâte, comme amaigrissant, d'un semi-coke produit à partir des charbons lorrains les moins cokéfiants (classes 721 ou 711) constitue une autre caractéristique importante de cette technique. Ce semi-coke réduit la contraction du chargement, et par là sa fissuration, comme le ferait le poussier de coke, mais il a l'avantage de ne pas exiger un broyage aussi fin que le poussier de coke, et la proportion qu'il est possible d'incorporer est plus élevée.

Ce semi-coke est fabriqué dans un four tournant d'un type déjà expérimenté dans plusieurs charbonnages pour la fabrication de combustibles sans fumée.

Par cette technique on peut, à partir d'un mélange composé de 75 à 80 % de charbon lorrain et seulement de 20 à 25 % de bon charbon à coke, obtenir un coke analogue

au coke métallurgique normal. On peut aussi obtenir un coke qui n'est que légèrement inférieur au coke normal avec une pâte intégralement constituée de charbons lorrains.

Le coût du coke obtenu par cette technique n'est pas plus élevé que celui du coke obtenu par les méthodes traditionnelles.

c. - Fabrication de coke de lignite

Tous les procédés connus de fabrication de coke de lignite à haute température exigent au préalable que le lignite soit mis en briquettes, de sorte que le lignite brut doit être d'un type approprié à cette première opération.

Les procédés existants pour la fabrication de lignite à haute température sont à deux temps ou à un temps.

La fabrication de coke de lignite à haute température est certainement d'un très grand intérêt pour les pays qui, sans être richement pourvus en houille indigène, ont à leur disposition d'amples réserves de lignite.

III. Carbonisation à basse et moyenne températures

Au cours des dernières années la distillation à basse et moyenne températures s'est considérablement développée non seulement à cause de la possibilité qu'elle offre de valoriser les lignites et les charbons, mais également à cause de l'importance des différents produits résultant de l'opération : semi-coke, goudrons et gaz. Les modes d'application de cette méthode sont nombreux; toutes les expériences ont conduit finalement à quelques systèmes de fours, chacun plus ou moins bien approprié à certaines conditions plus particulières et permettant une exploitation rentable du procédé adopté. Les fours utilisés à l'heure actuelle sont généralement des trois types suivants :

- fours statiques
- fours tournants
- fours faisant intervenir la technique de la fluidisation.

IV. Utilisation rationnelle des combustibles solides à fort pourcentage de stériles ou de fines en combustion industrielle

En raison des coûts relativement élevés de la production des combustibles solides, il est devenu indispensable pour les producteurs de charbon de retirer des produits le plus grand revenu possible, et pour ce faire, d'inciter les consommateurs à utiliser toute la production extraite de la mine. La préparation du charbon est absolument nécessaire pour certaines de ses utilisations provoquant la nécessité d'utiliser les produits intermédiaires: mixtes, poussières, schlamms. En ce qui concerne la combustion industrielle, la préparation du charbon peut être dans de nombreux cas évitée. Certaines idées semblent prévaloir en effet, à l'heure actuelle, concernant l'intérêt économique qu'il y aurait à utiliser les charbons sans aucun lavage conduisant à une utilisation plus rationnelle de l'énergie calorifique, étant donné d'une part les récents progrès accomplis dans la technique de la combustion et, d'autre part, l'utilisation de plus en plus grande des cendres volantes.

(a) Centrales de chauffe équipées pour l'utilisation de combustibles de qualité moindre

Il convient de citer :

i) Combustion en pulvérisé
ii) Foyers à cyclone
iii) Foyers avec pelleteur mécanique
iv) Foyers avec grille mobile à chaînes ou à barres
v) Foyers conçus pour la combustion des déchets de bois

(b) Utilisation des cendres volantes

Les résidus de la combustion de charbons cendreux représentent des masses considérables. Pendant longtemps on n'avait pas envisagé d'autre destination que les opérations coûteuses de transport et de mise en tas, qui peuvent atteindre 5 % du prix de revient de l'énergie produite. Les recherches entreprises ont permis de montrer que les cendres volantes possédaient des propriétés qui peuvent être exploitées, si bien qu'au lieu de constituer une charge, elles étaient capables de devenir une source de profit.

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Agenda Item : A. 3. 3. 1

Federal Republic of Germany

PROSPECTING METHODS ON GROUNDWATER IN LESS DEVELOPED AREAS, NEW WORKING METHODS AND THEIR APPLICATION

By Prof. Dr. H. J. MARTINI,
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Hanover

Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

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Prospecting Methods on Groundwater in Less Developed Areas.

New Working Methods and Their Application.

by
Prof. Dr. H.J. Martini, President of the Geological Survey of the Federal Republic of Germany (Bundesanstalt für Bodenforschung), Hanover.

Groundwater prospection is an important problem of Technical Assistance in less developed countries.

The base for technical prospection, such as the sinking of boreholes, are hydrogeological, incl. geophysical, investigations in the field; also the runoff is to be considered. Extensive operations done by the BUNDESANSTALT FÜR BODENFORSCHUNG in less developed countries in the Mediterranean, the Near-, Middle- and Far East, in Central- and North Africa and in South America, viz. under arid, semi-arid, humid and tropic climatic conditions, have shown the suitability of groundwater investigation teams to be set to work in such regions; with a minimum in personnel and equipment, such teams are in the position to obtain a maximum in results, with relatively little expenditure of time, on account of their outfit with most modern means and methods. The smallest unit of such a team consists of one hydrogeologist, one geophysicist and one engineer; additionally there would be a soil scientist, if the prospection aims also at irrigation purposes.

Such a team is equipped, in particular, with a chemical field laboratory and with apparatus for the performance of geophysical investigations. This outfit, constructed chiefly on the principles of own develop-

ments in the BUNDESANSTALT FÜR BODENFORSCHUNG, is adapted to every kind of climatic conditions; it can be used reliably also in tropical regions. The small dimension of the equipment makes possible its transport also by air into the region of operation.

The chemical field laboratory will furnish the hydrogeologist with analyses already during reconnaissance and thus will provide him with indications useful in projecting his field work. Hardness, pH- and chlorine content in waters can be determined.

In geophysical techniques geoelectrical resistivity measurements on the soil surface according to the "Four-Point-Method" are well to the fore. This method mediates a concept about the sequence of strata in the underground down to several hundred meters. A fully transistorized tropicalized highly sensitive instrument, developed for this particular purpose - smallest voltages less than 10^{-5} Volt can be measured in the field - has proved its value in an excellent way in all previous enterprizes. Results obtained so far proveded in all cases valuable conclusions on the geological structure of the underground in general, the distribution of aquifers and impermeable beds, and the course of the fresh/saltwater interface in regions where, according to geological conditions, saltwater is expected. Geoelectrical techniques are an auxiliary means to be employed with relatively little expenditure in the endeavour to get a picture, both large-scaled and local, about useable groundwater resources even in greater depths.

So for instance, in 1959, freshwater sources were encountered by this method in the Chaco Boreal of Paraguay. Moreover, a wide-spaced reconnaissance survey furnished a conception on the total groundwater balance of this region. In the Ganges Plain of East Pakistan, 1960, water-bearing sands could be delimitated against clayey/loamy impermeable

sediments. This was the base for initiating 300 water drillings. In 1961, a hydrogeological team operated in Indonesia. Here, geoelectrical techniques were applied in a karstic region in Central Java, and for groundwater development in limestones on the Isle of Madura.

An instrument constructed for seismic refraction measurements without using explosives was tested by a team who, in 1962, carried out groundwater investigations in the Damascus Basin in Syria.

Examinations for employing geothermal methods, which naturally are applicable only in areas with appropriate climatic conditions, have also been initiated. Good results are to be expected especially in karstic regions.

The results of large-scaled surveys have been documented in hydrogeological maps. As an example may be pointed out the Hydrogeological Index Map 1 : 250.000, of the Isle of Madura (Indonesia) which for the first time had been submitted on the occasion of the ECAFE Seminar Bangkok, 1962, by the BUNDESANSTALT FÜR BODENFORSCHUNG in cooperation with the Geological Survey of Indonesia. This map represents the basic material for developing waterprospective areas.

In prospecting for irrigation it was found useful to combine hydrogeological basic work with adequate soil scientific investigations and to supplement the team by a soil scientist as this has been done in Paraguay in 1959, and in Egypt in 1960.

Counterparts in the less developed countries have proved to be a considerable help in all work. Whilst the counterpart scientists contribute towards the understanding of their country, in all essential respects, the scientists of the team mediate the present state of science in the country rendering the "Technical Assistance".

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Agenda Item: A. 3. 3. 1

Italy

SOME HYDROGEOLOGICAL AND GEOPHYSICAL CRITERIA ADOPTED FOR GROUND-WATER RESEARCH IN THE HIGH NILE RIVER VALLEY AND THE RESULTS THEREOF

By Prof. V. COTECCHIA
and L. SOLAINI

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SOME HYDROGEOLOGICAL AND GEOPHYSICAL CRITERIA ADOPTED FOR GROUND WATER RESEARCH IN THE HIGH NILE RIVER VALLEY AND THE RESULTS THEREOF -

No. 2111, 2131
A.3.3.1

by
Proff. V. COTECCHIA and L. SOLAINI

1 - Foreword

In the years 1960-61-62, the ITALCONSULT carried out, for the account of the Ministry of Land Reform of the U.A.R., a survey to plan a series of land improvement and irrigation works for the agricultural valorization of some desert districts of High and Miggle Egypt. In the framework of this survey, the authors were able to carry out locally ground water studies and research; the criteria of this research are briefly illustrated in this paper.

In order to frame the problem and particularly the fact that underground waters are not directly supplied from the atmosphere throughout the Egypt territory, it must be stated in advance that all that regards temperature, rainfalls, atmospheric humidity, winds and sunlight hours of the region is typical of mainly arid tropical zones. Therefore, considering tha difficulties concerning the supplying of the aquifer strata the researchers were faced first of all, with the necessity of carrying out a geological and geohydrological survey of lithological formations emerging both inside and outside the land-improvement districts to study.

For the study of relationship among the various hydrogeological units with respect to the Layers ascertained both through surface geological survey and through mechanical drillings, a geophysical research was later carried out. The geological differences in depth, known through geophysics, were especially sought after for the information they might supply with regard to the consistency of the aquifers, the pick up depth of surface or deep waters, and, in some cases, to establish a comparison between the stratigraphic features of the soil of the Nile bed and those of the soil where phreatic water phenomena take place on the banks of the river itself.

Mechanical drillings were carried out, sometimes, with both a geognostic and hydrological aim so that all hydraulic measurements (flow, permeability, phreatimetric) necessary in order to define practically the problem stated with a purpose for the utilization of well water.

2 - Geognostic Research

This research aimed above all to studying the areas where there was an underground water circulation, within the districts that were to be covered. These particular districts are from 5 to 15 kms from the Nile, and begin where the actually cultivated land ends, spreading toward the desert inland (fig. n.1)

From the morphological point of view, in the area which is being studied, broad valley sections (Wadi) are found, having bottom height around 80-90

metres above sea level, and seldom conveying meteoric water. The actual cultivated area in Egypt is few kilometres wide and is generally completely flat. The new districts, instead, are more irregular.

The geological environment, a survey detail of which is shown in fig. 1, is characterized by a series of sedimentary rocks at its surface; this formation 400 or 500 m thick covers the crystalline rocks of the base. Deep geognostic drillings have enchanced the results of surface geological surveys and of geophysical prospections. An accurate paleontological study of the samples extracted has contributed, however, to the knowledge of the region from the geological point of view.

The sedimentary spreads from the alluvial loose deposits of recent wind formations to the Pleistocene terrace alluvions, to the blue-grey Pliocene clays, to the limestone and marly Eocene limestones, down to Cretaceous clay, sandstone, and phosphate beds alternances. Finally, at the base of the sedimentary, there are the well-known Nubian sandstones, generally with no fossils, sometimes glauconite in large subhorizontal banks, with medium and fine grain, subjected to a tectonic vertical fracture.

Moving Northwards along the Nile river valley, at Assuan, the pre-Cambrian crystalline (granites and syenites) plunges beneath the sedimentary, never to reappear North of Assuan. The Nubian sandstone, widely outcropping up to Assuan, disappear near Kom-Ombo, only to appear again in very narrow spots between Idfu and Isna. Coming out of the Nile river valley, especially Westwards, surfacing Nubian sandstone spreads very far North, greatly affecting the New Valley.

On the basis of the datas ascertained through the geognostical surveys and of the permeability characteristics of the formations crossed by the drillings the presence of the two already-mentioned different aquifers stratum are evident. The first concerns the loose gross quaternary deposits with a permeability for porosity, while the second concerns deep Nubian sandstone, there where they appear in powerful banks, interested mainly by a fissure permeability. The ground water being into the quaternary sand and gravels, alongside the Nile's banks and at water level, is separated from the deep artesian aquifer stratum by all the thick series of impermeable Tertiary and superior Cretaceous formations, which extends from the Pliocene clays all the way to the Nubian series, where this shows abundance of impermeable silt strata. This aquifer stratum does not exist where its impermeable bed surface lifts above the Nile's level.

As to permeability characters of the Nubian series, fractures have appeared to be rare and of permeability almost irrelevant for practical purposes as it happened in well WA 5 B, where clays strata prevail, which happens at the basis of the series, water-bearing fractures are more frequent and cause several aquifer strata under pressure, located at various depths, separated from one another by impermeable alternances richer in clay clayers.

On the basis of the hydrogeological elements thus ascertained, it was possible to plan conveniently both the geophysical and the strictly geological hydrogeological research.

3 - Geophysical Prospecting

The main themes with which geophysical research is concerned were

two: a superficial and a deep one.

The first was the traditional determination in water research of the contact between recent superficial formations and Pliocene clays.

The deeper them was more complicated, as it had a double edge; in fact, when searching for deep waters, it is important to determine the so-called Nubian sandstone formation, and therefore also the two contact surfaces the top one with clay formation (Eocene limestones are lacking in the zone) and the lower one with its crystalline bed.

The only system applied in the survey was that of the vertical electrical sounding, as it is easier and less expensive than seismic methods, which, however, might have been successfully employed and would have been, as we shall see, very useful.

Naturally, the small irregularities of the contact between the alluvion and the clay were of great interest, and therefore the superficial survey required a rather sizeable quantity of electrical soundings; the shape studied with much detail.

For this reason, only one third of the electrical soundings has a length spread sufficient to reach at least 500 m deep, while all the others are very shallow.

The possibility of individuating a formation by the electrical method depends, as it is well known, on two essential elements: the ratio between the resistivity of the formation itself and that of the two top and bottom formations, as well as on the ratio of the thickness of the formation and its depth.

We shall now see, on the basis of the conditions that have been exposed, the aspects of research in the area of Isna, in the solution of these two problems.

The first problem is usually worked out very easily; however, in several zones of the Isna territory, and much more in other areas South of it, as Wadi Abbadi and Saida, two remarkable difficulties have been met with.

The more superficial layer of the alluvial formations is composed of very thin sand, absolutely incoherent and naturally dry. Its resistivity is therefore very high for several meters, in the range of 10^3 - 10^4 ohm m. The permeable formation, instead, drenched with water, has a much lower resistivity, of few scores of ohm m; finally, clays have a resistivity of few ohm m. In such conditions, if the thickness of the first is half or less as that of the second formation, the curve practically may be confused with a two layer one and the determination of the middle layer is impossible. The permeable formations imbued with water are confused with the basic clay; electrical research, in such cases, may only give the top of the first layer.

All experts are well aware that crescent and decrescent resistivity successions are those which make interpreting more difficult. In such cases, the process indicated by Dr. Alfano may be useful (+). It consists of the use

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(+) L. Alfano - Geoelectrical prospecting with underground electrodes - Geophysical Prospecting, vol. X-N.3 - 1962

of electrodes placed at a certain depth in the ground.

The contemporary use of electrical profiles and of some seismic profils, limited to the most difficult zones, may diminuish remarkably this hindrance.

The second difficulty which was met is the enormous contact between electrodes and ground, which would often reach several hundred thousands ohm m. It has two negative effects: first of all, the current that one may succeed in conveying into the ground decrease even down to few mA, which is absolutely inadequate soon reach rather low values. The other obstacle consists of the fact that the resistance of the potentiometric circuit grows enormous and even so they are far from easy.

This problem, which seems at first irrelevant and easily surmountable gave very much trouble to the Foundation team operating in Egypt.

Let us now consider the problems of deeper research. The situation looks opposite than when the surface is concerned, at least as for as resistivity is concerned. In fact, sandstone is more resistant than the clay above, and the crystalline rocks are much more resistant than sandstone. In this case if the sandstone's thickness is the same, or lower, than that of the clay, the three-strata curve coincides almost perfectly with a two-strata one and the identification of the average-resistant formation is impossible.

Moreover, considering the fact that, on top of the clay, there is another resistant formation, it is easily understood how things grow considerably worse. One may infer, therefore, that the electrical method may be useful, in such cases, only when there are very thick formations covered by very thin ones.

Unfortunately, it often happens that the intermediate formations are not very thick, and therefore the electrical soundings are absolutely powerless. This is especially true in cases such as Isna's, where the intermediate formation's resistivity - that is, the nubian sandstone's - is not much higher than the clay's; both because the sandstones are alternated with clay, and because the water they are imbued with is salty enough.

In order to overcome this difficulty, one may resort to refraction seismis or to combined refraction and reflection, because the elastic modulus contrast between the sandstone and the clay above is quite sharp. Furthermore, seismic methods have a much higher selective power than electric ones.

Electrical soundings have revealed a bed formation definitely resistive which, evidently, was to be credited to the base crystalline formation from the start, on account of its high resistivity. It was impossible to establish whether or not there was an intermediate formation. A drilling met 200-m-thick Nubian sandstone, leaning on the crystalline, at 260 m depth.

The ratio between the thickness of the sandstone and clay formations is slightly lower than 1, therefore this is the case where a correct intepretation is impossible. A very careful examination of the electric soundings, however, has permitted to remark the presence of sandstone in a few zones and to calculate their depth, though with some uncertainty. Generally, however, in spite of all efforts, interpretation is actually impossible.

So far, we have only mentioned difficulties; we must say, however

that, aside from the problem of sandstone location, electrical prospecting in zone of Isna was very successful, since it was possible to trace a very detailed map of the level lines of the impermeable formation's top (fig. 2), and also, is its broad outlines, the crystalline top.

The soundings were distributed rather evenly, with an average density barely superior to 1 per km^2; only 46 of them have a 4 km length, and this the reason why the bed itself could only be followed in its outline. All other soundings - more than one hundred - have total spreads lower than 1 km.

Electronic-voltmeter measuring instruments were very helpful, because of their high sensivity, which allows acceptable results even with currents, of their high input impedance, which makes measurements possible even with very high contact resistances of the electrodes; and, finally, for the quickness and exactness of their measurements.

4 - Hydrological Surveys

Drillings - Mechanical drillings with a hydrological goal were carried out with a sufficiently wide diameter (10" and 12") in order to accomplish the regular pumping tests with submerged pumps. Drillings with a much lower diameter (2" and 4") were carried out for the purpose of piezometric controls of the water-table. Usually the percussion system was applied for loose formations and depths up to 60-70 m; the rotary system had to be resorted to for greater depths and stone formations.

Phreatimetric strata surveys and measurements of the Nile river levels-

Through periodic phreatic stratum controls, it was possible to obtain very interesting datas regarding the movement of the water-table of Isna and Samalut, as well as on the reloading features of the Nile river downflows and of the absorption of irriguous waters taking place in already cultivated areas.

A regulation weir at Isna on the Nile river modifies remarkably the downflows at the heights of the river, up and downstream of the weir, with the evident consequences on the regime of the water-table stratum. In the diagram at fig. 3, the two phenomena of flood and the two ones about low water are clarly shown.

In the Isna district, the water-table oscillations are characterized , however, by a trend parallel to that of the river, with a delay going from two to four months. Through the whole series of phreatimetric stratum surveys, in these cases, it is possible to achieve a set of indicative notions with regard to the behaviour of the water-table stratum, as far as its filling again and downflows toward the Nile river.

In the Isna district, water-table oscillations appear extremely low when compared with the levels of the Nile. In order to understand such a phenomena, which is certainly common to all other water-tables strata in the same conditions in the Nile river valley, it is very interesting to know what was ascertained in this district through the hydrological controls that were carried out. Where, when ground-water stratum is in the exhaustion phase, the Nile river flood takes place (in the trimester of August - September - October), with the consequent filling again from the left bank of the river of seepage

water; at the same time, the basin-and-canal irrigation in the cultivated land begins to work fully. The exhaustion of the ground-water stratum, in such conditions, is thus checked by the irrigation; indeed, a new rise phase begins, more or less at the time when the Nile river flood is beginning to exhaust (November). Therefore, it must be assumed that the aquifer receives no real supplies of seepage water from the Nile; rather, the vadose water percolation, deriving from the irrigation, have a sizeable influence on the filling again of the aquifer stratum. Later, as the water-table stratum trends to its highest level, the Nile river levels reach a minimum peak (December), followed by a new flood which reaches its maximum in February; in the aquifer stratum instead, an exhaustion cycle is taking place. This, however, is remarkably checked by the irrigation of the months from April to August, which is uninterrupted throughout such a long period of time. Consequently, when the irrigation is farily advanced, the water-table stratum touches a new maximum. The limited size phreatimetric oscillations, when compared to the Nile's, gives the impression of a practically stable equilibrium; this impression is due to the complicated action of the various influences caused by the filling again of the Nile and by those deriving from vadose irriguous absorption waters.

Piezometric quotas of the deep aquifer stratum -

In the well WA 4 C the first waters in pressure of the Nubian series was found at about 200 from the ground surface (g.s.) (-100 m below sea level); in the well IS 2 A/B/ the Nubian series waters were found in the section at 350-450 m below the ground surface; at 465 m below sea level the crystalline substratum in the form of diorite was found. The well WA 5 B at a depth of 500 m g.s. appeared still sterile from an hydrological point of view. The artesian waters found at Wadi Abbadi showed temperatures of 29° c, those found at Isna 39° C and levelled at 104 m above sea level.

Capacity of the wells and comparison with the techniques adopted in drilling -

Pumping tests proofs and tracings of characteristic curves fro each research well, were meant to ascertain not only the real output of the wells, but also the efficiency of the various methods experimented in the drilling and of the covering adopted.

It is interesting to point out how, for example, four months after the end of the preceding pumping test, the well IS 4 A deceased considerably its average specific capacity down thus showing the partial occlusion of the filtering part of the covering columns, made of metal pipes of a Ø 10"1/2 diametre, fissured and lined with a close brass net (Reps). From several comparisons of this kind, the conclusion was drawn that the best outputs of the wells are consequential to the drilling diametre, a convenient draining around the filtering walls of the tubings, and, finally, to the kind of filter used. In medium grain sands, which are often the medium of the aquifer in the Nile river valley, the special anti-sand filter with bridge elements (Slotted Bridgetype) is more suitable than Reps nets. Also in deep wells, dug in Nubian sandstone, the remarkable decrease of hydrological output caused by betonite muds during the drilling was noticed.

Permeability tests-

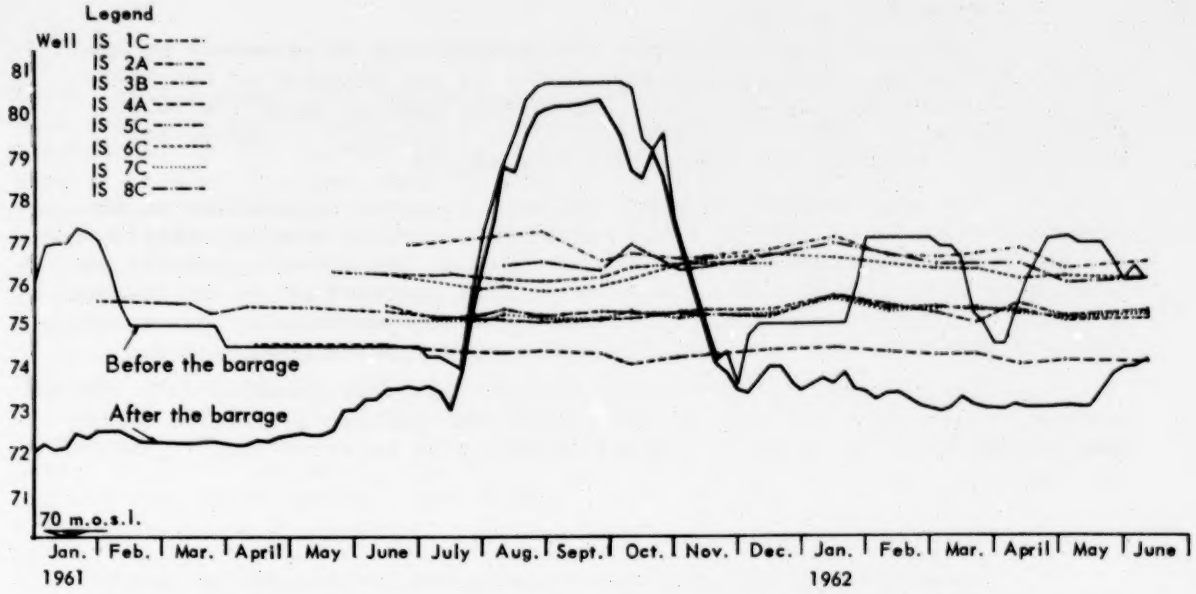
Completing capacity tests, the permeability measurements of the aquifer have given elements extremely useful in the planning of the wells and of the operating capacity to be allotted to each of them. The well-known formulas of DUPUIT and THIEM have given , majority of cases, not very reliable results, much lower than real values.

The most dependable results derived from the application of the procedure proposed by PUPPINI, with regard to permeable complex constituted generally of hetherogeneous elements. For each of these tests, special spy-pipes have been placed around a main well fully penetrating in the aquifer. By means of these pipes, a few level curves of the depression cone, ground the well corresponding to a definite regime output, have been traced.

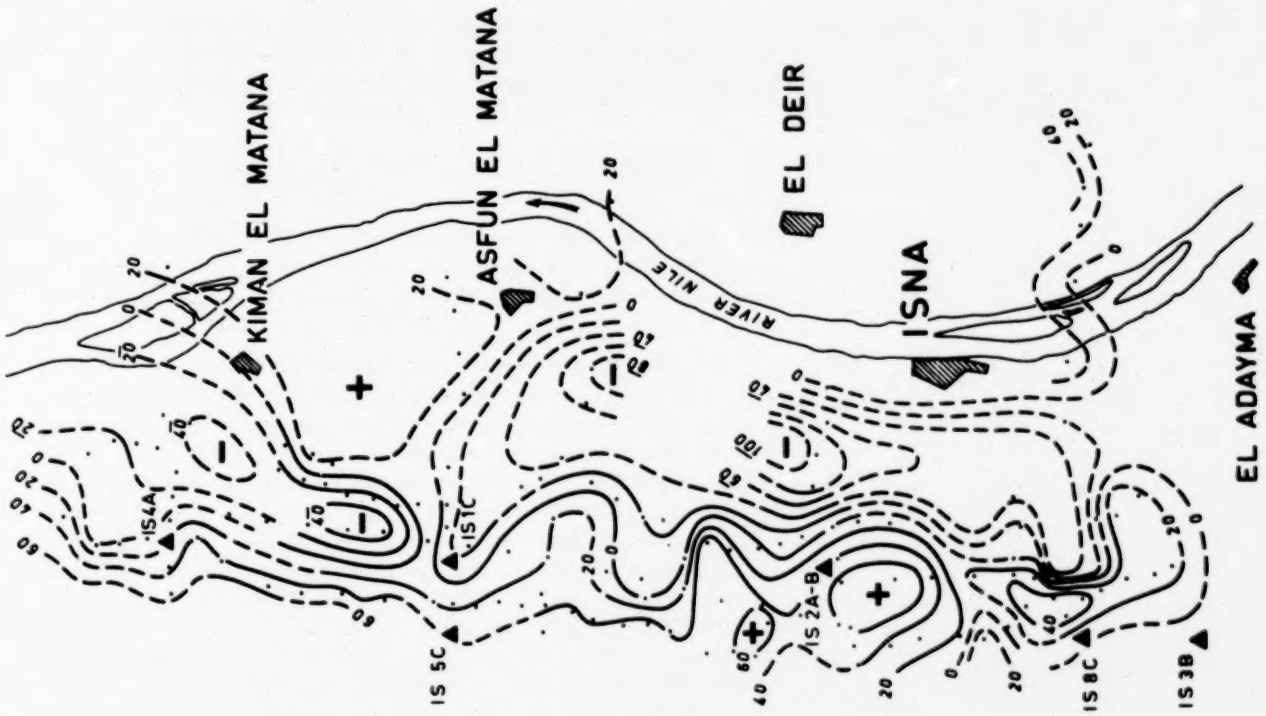
In the Isna district, the permeabilities thus measured have reached average values of 0.20 - 0.25 cm per second. The aquifer discovered in the Samalut district has shown an average permeability value of about 0.10 cm per second.

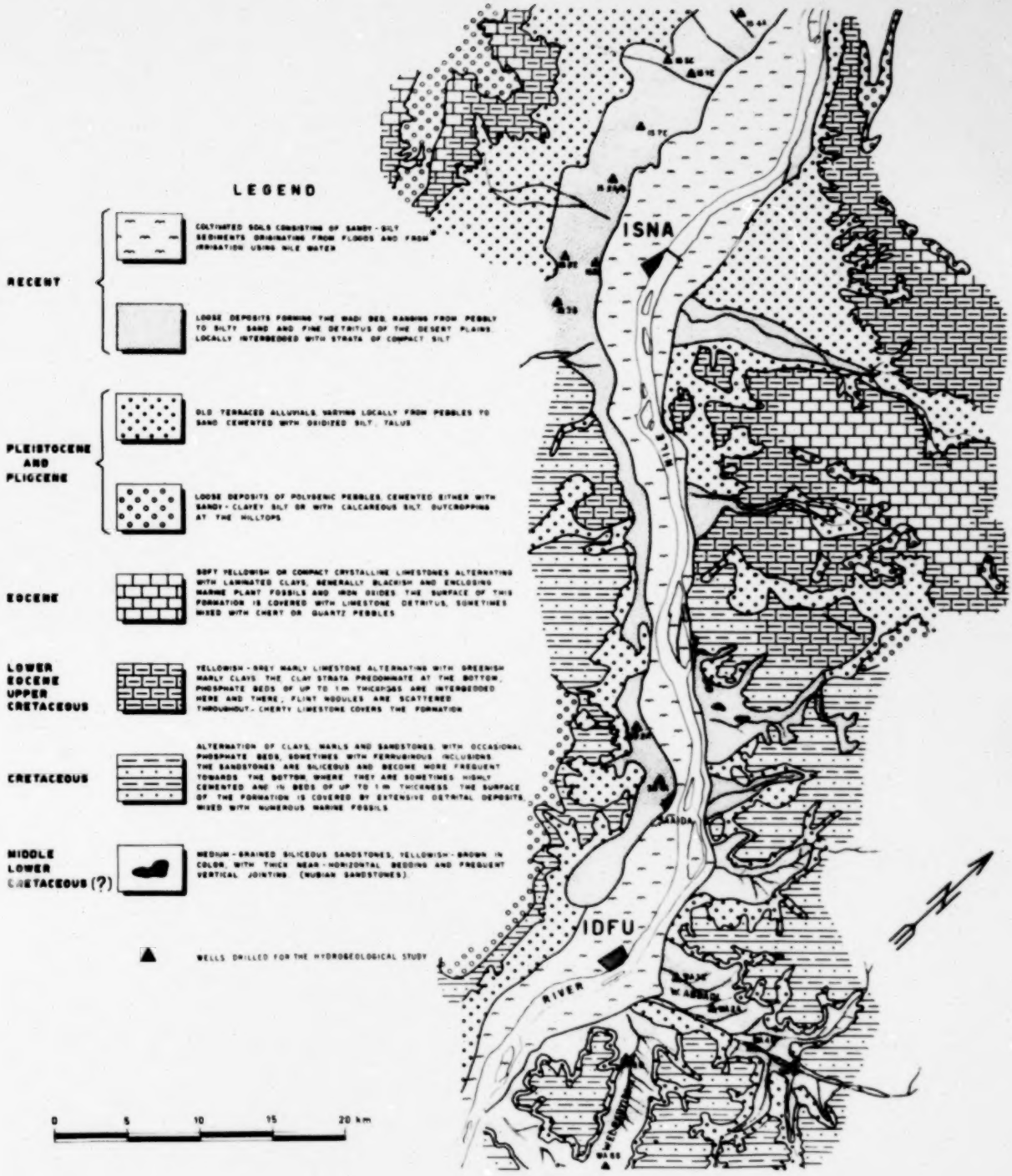
Quality of the waters -

Detailed chemical analyse were being carried out during pumping-tests, with results of interest with regard to the influence of the soils on the quality of ground waters. Where the aquifer stratum appeared thick as, for instance, in most of the Isna district, the salt residua ranged from 0.25 to 0.50 g per 1 (Whole the Nile river water has a salt remanent of 0.10 g. per 1.). On the other hand, in areas with little presence of phreatic water strata these reached residues of the range of 1.25 - 1.50 g. per 1., with very high Cl and SO_4 concentrations, deriving from the salt melted in the soils crossed by vadose waters. The ground-water of the nubian sandstone stratum showed all over very high salt residues, up to 2.30 g. per 1., in most part constituted of chlorides, sulphates and ferrous oxides.



Nile's levels oscillations at the Isna Barrage during the years 1961, 1962




LEGEND
RECENT
CULTIVATED SOILS CONSISTING OF SANDY - SILT SEDIMENTS ORIGINATING FROM FLOODS AND FROM IRRIGATION USING NILE WATER
LOOSE DEPOSITS FORMING THE WADI BED, RANGING FROM PEBBLY TO SILTY SAND AND FINE DETRITUS OF THE DESERT PLAINS, LOCALLY INTERBEDDED WITH STRATA OF COMPACT SILT
PLEISTOCENE AND PLIOCENE
OLD TERRACED ALLUVIALS, VARYING LOCALLY FROM PEBBLES TO SAND CEMENTED WITH OXIDIZED SILT, TALUS
LOOSE DEPOSITS OF POLYGENIC PEBBLES CEMENTED EITHER WITH SANDY - CLAYEY SILT OR WITH CALCAREOUS SILT, OUTCROPPING AT THE HILLTOPS
EOCENE
SOFT YELLOWISH OR COMPACT CRYSTALLINE LIMESTONES ALTERNATING WITH LAMINATED CLAYS, GENERALLY BLACKISH AND ENCLOSING MARINE PLANT FOSSILS AND IRON OXIDES. THE SURFACE OF THIS FORMATION IS COVERED WITH LIMESTONE DETRITUS, SOMETIMES MIXED WITH CHERT OR QUARTZ PEBBLES
LOWER EOCENE UPPER CRETACEOUS
YELLOWISH - GREY MARLY LIMESTONE ALTERNATING WITH GREENISH MARLY CLAYS. THE CLAY STRATA PREDOMINATE AT THE BOTTOM. PHOSPHATE BEDS OF UP TO 1 m THICKNESS ARE INTERBEDDED HERE AND THERE, FLINT NODULES ARE SCATTERED THROUGHOUT. CHERTY LIMESTONE COVERS THE FORMATION
CRETACEOUS
ALTERNATION OF CLAYS, MARLS AND SANDSTONES WITH OCCASIONAL PHOSPHATE BEDS, SOMETIMES WITH FERRUGINOUS INCLUSIONS. THE SANDSTONES ARE SILICEOUS AND BECOME MORE FREQUENT TOWARDS THE BOTTOM WHERE THEY ARE SOMETIMES HIGHLY CEMENTED AND IN BEDS OF UP TO 1 m THICKNESS. THE SURFACE OF THE FORMATION IS COVERED BY EXTENSIVE DETRITAL DEPOSITS MIXED WITH NUMEROUS MARINE FOSSILS
MIDDLE LOWER CRETACEOUS (?)
MEDIUM - GRAINED SILICEOUS SANDSTONES, YELLOWISH - BROWN IN COLOR, WITH THICK MEAN - HORIZONTAL BEDDING AND FREQUENT VERTICAL JOINTING. (NUBIAN SANDSTONES)
WELLS DRILLED FOR THE HYDROGEOLOGICAL STUDY
ISNA
IDFU
NILE
RIVER
0 5 10 15 20 km

GEOLOGICAL MAP

OF THE NILE VALLEY BETWEEN WADI ABBADI AND ISNA

1650 E - Nov. 1962 - 1,600

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UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item : A

United States of America

NATURAL RESOURCES POLICIES AND PLANNING FOR DEVELOPING COUNTRIES

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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NATURAL RESOURCES POLICIES AND PLANNING FOR DEVELOPING COUNTRIES

by
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1. Developing countries need to know a great deal about their natural resources of land, energy, water, and minerals, and about the industries, products, and services closely associated with them. They also need to make headway in translating that knowledge into programs of development. These two closely associated goals are important to developing countries because resource industries are dominant in their economic life, because improvement in the resource sectors usually is a prerequisite of escape from situations in which rapid population increase is accompanied by low productivity and income, and because raw material exports frequently have to be depended on for foreign exchange with which to purchase needed capital equipment. Furthermore, subsequent growth will be conditioned by the pattern of location of population and industry and by the development experiences established during the earlier phases of economic development when natural resource occurrences and characteristics are more influential.

2. The central purpose of this paper will be to characterize the role of resource policies and plans in the advancement of less developed countries. Resource policies, which are the more general principles and guidelines for development, and resource planning, which translates policies into concrete terms for land, water, energy and minerals, may be thought of as the connecting links between science and technology on the one side and higher economic and cultural attainments on the other. Of course, natural resources do not tell the full story of economic development; a skilled and capable labor force, capital plant and equipmen , an enterprising and well trained cadre of industrial managers, and impartial and decisive government administration are also vital. However, in a real sense, the whole economic pyramid rests upon raw materials and environmental resources and realization of their potentialities through the application of science and technology.

3. These considerations and others to be examined later have already been found to be of great importance in the developing countries, many of which have been making notable headway in analyzing their resource potentialities and translating them into effective policies and plans. In this paper we shall try to summarize the broad objectives of resource policy, to consider the conditions favorable for rapid and sustained progress in resources development, to indicate some principal elements of resource policy making and planning, and to discuss these elements in terms of specific situations in a selected less developed country. Finally, we shall point out several significant problems or obstacles to resource development that are common to many less developed countries.

Characteristics of Resources and Broad Objectives for Their Development

4. Natural resources differ from capital and other kinds of resources primarily in their relatively fixed geographic location and extent. Many raw materials can be extracted from the ground or harvested from the land and waters and shipped to distant points for consumption or further processing, but they all begin in a more or less fixed place and exist in finite amounts although neither the precise physical nor the economic extent may be known. There is the further characteristic that most resources are depletable in some sense. Mineral reserves in any particular location are depletable in an absolute sense; that is, they may be used up economically if not physically. The renewable resources of agricultural land, forests, grass lands, and fish populations may be exploited to the point where they can be reestablished only at prohibitively high cost, if at all. Another characteristic is that resources are the first links in the economic chain: resource materials enter technological processes early and then have applied to them varying degrees of fabrication and transportation on their way to becoming final consumer goods and services.

5. Every country needs to learn what resources it has, what their economic potentialities are, and how to translate mere existence into useable products and services. It must also determine where its comparative advantages lie and how these may change, since it will have insufficient capital, skilled manpower, or other means to develop all its resources in any given time period. This will mean for many countries a continuing concentration on food and fiber production for domestic consumption with less attention to production of mineral or agricultural raw materials for exports. For other countries the reverse will be true.

6. Each country will want to fit its resource development plans in with broader economic development plans. This frequently will call for investments and other activities to increase per-man and per-acre yields in agriculture along chosen lines, diminish over-all the number of agricultural workers, expand rapidly certain industries which at relatively low levels of capital intensity will make use of easily obtainable raw materials, and expand and diversify the energy base.

7. Economic activity in most of the less developed countries is heavily concentrated in the resource industries compared to more developed countries. In Brazil, for example, about 60 per cent of the labor force recently has been engaged in agriculture, forestry, fishing, mining, and quarrying; in India about 70 per cent; and in other less developed countries the percentage is even higher. In Italy, Japan, Mexico, and Spain the per cent of the labor force in resource industries has ranged in recent years from 40 to 60, while in the United States it is about 13 per cent. National income arising in the resource industries has also made up the larger part of total national income in nearly all the less developed countries, although the percentages are somewhat lower than those cited for the labor force, principally because of the lower level of labor productivity in agriculture than in industry.

8. Improvements in agriculture and the other basic resource industries in nearly every instance will be necessary if early stages of economic development are to be followed by diversified industrial development. All economic policies and plans therefore will be heavily oriented to resources. Resources, plus their transport and basic processing, become the core of development planning to provide food, water, building materials, heat, electric power, and many other items. First attention will usually be given to domestic sources for most of these, although a number of less developed countries have been able to export one or two particular raw materials in which they are especially well endowed as a means of obtaining yet other raw materials from other countries.

9. With these characteristics in mind the primary objective of resource policy may be stated. It is to promote the achievement of national objectives through development of land, water, energy, and minerals:

---at least cost;

---on a sustaining basis having in mind the conservation of existing supplies, the discovery of new sources, and the development of cheaper or more plentiful substitutes;

---with a high multiplying effect on further economic development;

---with significant contributions to better relations among nations for the advancement of all;

---so as to encourage a wide and equitable sharing of costs;

---so as to minimize or offset the difficulties of adjustment in particular regions and among particular groups.

10. Particular resource policies and plans may be tested against these objectives. Obviously these objectives overlap one another, are complex and difficult to determine in precise situations, and involve numerous contradictions. Policies and plans must be compromises among them. For example, least cost production in agriculture, if pursued relentlessly, might force large numbers of farmers out of agriculture and out of their particular farming regions before they could be retrained for other economic activities or before programs could be set in motion to aid them in adjusting to living in other communities. The requirements of national defense may also conflict with the least cost principle. Equitable sharing of costs is most difficult to define since it must be relative to individual values and broad social objectives which themselves are changing.

·Conditions for Progress in Resources Development

11. A number of conditions may be laid down for rapid and sustained progress in resource development. These will vary in relative importance from country to country, but will obtain to a significant degree in virtually all places. They include:

a. Increasing scientific and technical knowledge about resources, especially those on the more immediate horizon of development.

b. An improving professional education system for increasing the number of scientists, engineers, economists, industrial managers, administrators, planners, and others; and an improving general educational system in support of citizens' understanding of the part resources can play in economic advance.

c. Access to world sources of raw and processed materials and to world markets since self-sufficiency is either impossible or at least very costly for all countries.

d. Some containment, if possible, of the pressure of population at least in many of the less developed countries.

e. Reasonably stable government and competent administration.

f. Willingness to work hard and to save in the interest of more rapid development, to the extent of capacity.

g. Appropriate help from other more developed nations in finance, real capital, education, and technical aid on a carefully selected and fitted basis.

12. In many ways these conditions set out for progress in resource development are simply the specific application of the more general conditions of economic growth. Resource policies and plans must not only take them into account, but should aim at improvements leading to more effective utilization of new technology through increasing the skill of the labor force, fostering more efficient industrial management, providing lower cost electric power and heat, a better transportation system, and an increase of social capital in many forms.

Elements in the Resource Planning Process

13. Given the broad objectives for resource development and some knowledge as to the general conditions which will favor such development, how can the more specific and practical work of resource policy formulation and planning be improved? Two interrelated elements or aspects require consideration: framework and decision.

14. The framework element includes the relevant basic data (geologic, hydrologic, geographic, economic); social patterns and institutions within which resource development has to be worked out; systematic long-range estimates of demand and supply of resource materials as these are related to population estimates and foreseeable technologic changes; and the general goals of national and regional plans. The framework consists essentially of a layout of data, technologic possibilities, alternative supply sources, economic trends, institutional situations, and the like within which policy and planning decisions are made.

15. The decision element focuses on ways in which policy and planning decisions are actually made in public and private sectors of an economy. Decisions regarding broad policies for resources development, long-range development plans and budgets, particular resource projects, and administrative implementation are not clearly separated in practice; there is a continuum of decisions across a band from the more general to the more specific. Attention here will be given to the improvement of resource decisions by such means as benefit-cost, linear programming, and input-output analysis. These techniques can aid in appraising the merits of alternative resource development projects and systems of projects such as river basin development schemes and industrial complexes. Case studies of existing projects can also lead to improvements in future decisions. This element is concerned with the whole process by which decisions are reached; with the political, social, and aesthetic factors as well as the technologic and economic, and therefore with the points of view of various groups and with the conditions that have to be satisfied if their support, or at least acquiescence, in the decision is to be assured. It is not too much to say that the primary objective in resource planning is to establish an efficient decision-making process, important though particular investment and other decisions may be.

Framework

16. Resource policies and plans have to be visualized in various contexts: one of the most useful of these contexts is the long-range interrelated projection of demand and supply for resource products and services. Such a set of estimates may be made: first, by projecting the larger economic and demographic aggregates such as population, labor force, gross national product and its major components, and the like; second, deriving from these chiefly on the basis of historical relationships the demand for such resource products as meat, cotton, steel, construction lumber, fertilizer, and the like; and third, calculating the requirements for the basic resources of crop land, forest land, water, energy commodities, and metals from which products in the second stage may be produced. In this manner a bill of requirements for resource products and the basic resources themselves may be worked out within the constraints of anticipated increases in

population, work force, productivity, and national production. It will be helpful to work with ranges, probably quite wide ranges for years farther into the future, which will embrace a high, a low, and one or more intermediate estimates. Precisely where actual demand falls within the range will depend on how new technology is applied in industry, how consumer wants shift, the extent to which new sources at home or abroad open up, and the directions and effectiveness of policies designed to change the course of events which otherwise would follow.

17. On the supply side, the estimated requirements would have to be met within the overall constraints imposed by quantity and quality of known and potential natural resources as well as by the technical and economic capacity of the country or area in question to discover, extract, process, transport, and utilize these resources or those it can obtain from other countries. Technology and economics will form the bridge between estimates of demand and the manner in which they are satisfied. With skillful balancing of the variety of supply possibilities with estimated demands, with careful attention to the estimating of net returns of alternative courses of action and to economies of scale, development of the economy can proceed along efficient lines. One of the greatest difficulties in building this kind of framework will be the uncertainties which surround new technology and the rate of application of existing technology, and this is especially true for less developed countries.

18. Such a framework of projections is well suited for exposing incipient gaps between projected demand and likely supplies and for making estimates of possible changes in the relative prices of resource products.

19. This kind of exercise has been done for resources in the United States.[1/] The resource demand estimates, which are derived from projections of basic demographic and economic aggregates such as labor force and production, have been used as reference points in the analysis of supply possibilities and difficulties. For example, in the energy resources field consumption of all fuel and power, measured in a common unit, is estimated to increase about threefold by the year 2000 compared to 1960, while population is estimated to increase about 85 per cent and gross national product by more than four times. Within the total estimated increase in all energy, the shares of the several energy commodities and sources are expected to change. The most dramatic prospective shift will be in atomic energy; relative shifts among the conventional sources of coal, oil, and natural gas will be less marked than during the past century. Demand estimates (perhaps they should be called speculations) show atomic power to increase from virtually nothing in 1960 to 480 billion kilowatt hours in 1980 and 2,500 billion kwh in 2000, by which time well over half of the new electric power installations may be nuclear reactors. These are medium level estimates; a wide range of possibilities exists. The conventional fuel sources of coal, oil, and natural gas are expected to increase also but at much slower rates; by 2000 the demand for oil may increase by three times, natural gas by nearly that much, and coal by about 75 per cent.

20. Built into these projections of atomic power and other energy sources are numerous assumed changes in technology, some of them major. Failure to achieve considerable cost reductions in the production of atomic power will mean that conventional energy sources will have to be relied upon much more heavily, or other new sources such as oil shale, tar sands, low grade coal, and possibly unconventional sources will have to be drawn upon, if the energy sector is to grow in total as projected.

1/ Landsberg, Fishman, and Fisher, Resources in America's Future, to be published in the spring of 1963 by the Johns Hopkins Press for Resources for the Future, Inc.

21. Estimates of investment requirements for enlarged raw material production may be related to projections of demand for the materials themselves. Foreign trade enters into the picture in several ways: foreign demand has to be added to domestic demand for domestic raw materials, foreign supplies have to be subtracted from total supplies needed in order to get what will be required from domestic sources. A long range, interrelated, demand-supply framework such as has been described can help to set the stage of more realistic resource policies and plans, although it will not specify what the policies and plans have to be. The projections bring major problems into focus and narrow the range of useful courses of action. The working through of these projections requires at least a minimum knowledge of aggregative demographic and economic trends, of technical relationships between resource inputs and outputs of resource products and services, as well as scientific and technical knowledge about the basic resources themselves. The greater the amount and the higher the quality of such information, the more realistic and useful will be the framework of projections. Wide ranges in the demand estimates will be the better part of wisdom; policies based upon such projections should also be flexible so that they may be altered in the light of unfolding events.

22. Another useful instrument for framework planning is comprehended by the term systems analysis, by means of which a resource complex is stripped of non-essential elements and placed within a model that expresses the significant interrelationships. The principal variables may then be manipulated in such ways that the output or performance of the system can be described quantitatively and tested against performance criteria. Typically, high speed computers will be necessary to do this. Systems analysis in this sense has been experimented with, both in theory and in simulated practical applications in a number of resource situations including river basin development schemes. 2/ This kind of engineering-economic analysis can throw much light on the efficiency of alternative development programs and, placed in relevant political and administrative formats, can aid greatly in reaching wise decisions. Still other kinds of framework exist or can be constructed,-for example, legal, administrative, and institutional, which can aid in placing resource planning in better perspective, but these are not elaborated here.

Decision

23. The processes of policy-making and planning are carried on within whatever frameworks (demand-supply systems, legal, institutional, and others) may be constructed. How may these processes be made more effective so that one project or phase of the actual plan that is undertaken may lead easily and logically into the next? Here we are concerned with the strategy and sequence, with the smooth meshing of the several parts, in such a way that initial impulses toward development can exert a multiple effect on the economy and the whole plan can move toward fulfillment with a minimum of delays and detours. Especially we are concerned with the way in which policy and planning decisions are made and with their quality and effectiveness. The improvement of decisions is to be achieved partly by better facts and analysis, and partly by improving the way in which facts and analysis are used. On issues of major significance decisions are governmental decisions in the public sector and top management decisions in the private sector. Over all are the broad political decisions as to national goals and policies; underlying all are the preferences, motivations, and actions of individuals.

2/ Maass, Hufschmidt, Forman, Thomas, Marglin, and Fair, Design of Water-Systems, (Harvard University Press, Cambridge, 1962).

24. Several kinds of analysis may be useful in guiding those who make decisions about policies and plans. One kind which has been used in the United States, especially in the water resources field, is called benefit-cost analysis. Essentially this comprises the identification of alternative projects for achieving roughly the same purposes, an estimate of the costs which will be incurred over the life of the project, and a comparison of the estimated benefits and costs for each of the alternative projects. Many difficulties arise in this kind of analysis, some of which have to be settled arbitrarily. What shall be the assumed length of life of the project? What would be the appropriate rate for discounting the flow of future benefits and future costs? Should the rate be related to some private market rate of interest or should it be a public or social rate? What course of prices and costs should be assumed for the future? Perhaps most vexing of all is the question of what range of particular benefits and costs should be included in the analysis at all; especially, should those of a more intangible, remote, and social nature be included -- and if so in what way?

25. Much attention has been given to benefit cost analysis in the United States and indeed for most water development projects federal law requires that such analysis be undertaken and the result presented to the Congress along with other information about the proposed project. Uniform procedures have been established and form the basis for field investigation of benefits and costs. Questions like those raised here have been given a good deal of critical attention in recent years, and as a result benefit-cost estimating techniques have been refined, somewhat more sharply delimited, and in general made more understandable and useful. Benefit-cost estimating for alternative resource development projects may also be helpful in less developed countries although lack of a competitive price system including a money market, the large size of many projects in relation to the resources available for accomplishing them, and the necessary emphasis on social purposes make the technique clumsy and ineffective in many instances unless it is severely limited to appraising the merits of specific alternative projects, for example, dams of different heights or in nearby locations.

26. Also of use in less developed countries may be the input-output kind of analysis in which the sectors of the economy are viewed in terms of the relationship between the input of resources and other items on the one side and the output of final products and services on the other side. Data can be gathered and organized in such a way that the coefficients expressing these relationships may be calculated and a matrix established. It then becomes possible to assume a mix of final outputs and calculate the inputs that will be required to give the desired results. Such a schema can be used to estimate the effects of alternative paths of national development; regional input-output matrixes would permit the testing of larger scale resource projects.

27. Several difficulties arise at once: a considerable amount of technical and economic data are needed, although to some extent the input-output technique can be used with a minimum of data; the technical coefficients relating inputs and outputs may change especially in countries growing rapidly and shifting toward more industry and more mechanized farming. This technique, however, does enable broad appraisals and comparisons of different sets of resource development projects to be made.

28. A more narrow and focused variant of this approach is the linear programming model in which outputs of particular items, for example, are regarded as a function of a number of independent and variable factors. With the relevant data inserted, such systems of equations may be manipulated in various ways and made to yield solutions which are optimal in terms of selected criteria. Other analytical methods useful in improving decisions include game and queueing

theories, simulation, minimax and related techniques.

29. In addition to these more technical means for improving policy and planning decisions, we must call attention to the importance of the way in which data and analysis are handled at the points of decision. Essentially this is a matter of organizing and bringing forward various kinds of evidence bearing on the policy or the plan in such a way that a comprehensive and balanced picture is made available to the decision makers at the time the decision has to be made. The evidence obviously will include engineering and economic analysis, and it should also include broad social, political, and aesthetic argument. The broader the policy or plan under consideration, the more general will be the evidence and argument. The more narrow and focused the policy or plan, the more specific and perhaps quantitative it can be. Finally there can be no substitute for well-trained, politically and socially sensitive persons in the decision making positions -- persons who will be able to bring together the various plans and analyses with a keen appreciation of the conditions which will have to be met if necessary support is to be obtained. Policy making and plan making at the higher and more general levels tend to be political acts concerned with the public sector or the regulation of the private sector. In national planning as carried out in most of the less developed countries, the scope and general role of the private sectors are also marked out in the plan so that the larger private resource decisions are embraced by and consistent with the public decisions.

Resources Planning and National Development: An Example from Pakistan

30. Resource policy and planning have to be viewed in the full context of national development if they are to serve that cause effectively. A development strategy must pull together the natural resource potentialities with the available manpower and capital resources in a dynamic program for resource and national development. Particular attention should be given to shortages and obstacles of a general economic nature (e.g. insufficient savings, foreign exchange, or trained manpower) and to those related more closely to natural resources (e.g. low agricultural productivity, high-cost energy materials for heat and power, or undeveloped mineral resources) Insufficient or poor quality data for better resource planning frequently will be the first obstacle.

31. The interrelationships involved in resource planning for national development and the need for a development strategy may be illustrated in the case of agriculture in many of the less developed countries where yields are depressingly low and have not risen very much in recent years. Usually more than one factor of productivity limits yields: lack of water at the right place and time, sometimes too much water, not enough fertilizer, farms too small in size, and others. An integrated and concentrated attack on these factors is needed and will involve communication with farm operators, social and economic analysis as well as much applied agricultural research, and better administration of agricultural programs. Achievement of initial momentum is essential but not at the cost of foreclosing future possibilities. Above all, a strong economic motivation on the part of farm operators and workers must be created. Program and expenditure choices usually exist -- for example, development of surface versus underground water, or new agricultural land versus more intensive cultivation of land presently farmed. In laying the basis for wise choices, interrelated social, economic, and engineering analysis, frequently using modern techniques such as those mentioned earlier, can be highly effective.

32. Many of the principles of resource development and the kinds of analysis useful in resource planning are revealingly illustrated by the problem of

agriculture in West Pakistan. 1/ The flat, fertile Indus Plain, most of which lies in West Pakistan, contains the largest single irrigated area on earth. With its sandy and silty soils, year-round growing season, large surface flow of water, highly developed system of irrigation canals, huge underground reservoir of fresh water, underground pools of natural gas, and a wide range of crops that can be grown, the Plain is one of the chief physical assets of the world's fifth most populous country. Yet, despite its potentialities, incomes from agriculture remain very low, and there is a deficit of both calories and animal proteins in the diet of the people. Population is increasing more rapidly than food production.

33. One of the problems of agriculture in West Pakistan is waterlogging and salt accumulation in the soil, caused by poor drainage in the vast, nearly flat Plain. Agricultural production is also held down by a shortage of irrigation water. Because of canal seepage and other losses, only about half the water diverted from the rivers is available to crops. Much of the planted area receives too little water to prevent salt accumulation. Chemical fertilizers, protective measures against plant diseases and pests, and high-yielding plant varieties are very little used. Other handicaps are the system of land holding and primitive methods of cultivation.

34. In establishing the framework for agricultural development, the need to raise present per capita food production by 30 to 40 per cent and the range of probable population growth in West Pakistan of between 50 and 100 per cent over the next 25 years must be considered. Increases in sugar and cotton production will be required to meet the demand of both East and West Pakistan. As living standards rise, the relative demand for fruits, vegetables, and livestock products will grow. Additional increases in agricultural production will have to be based on export markets or industrial use of farm products.

35. Maps of the mechanical composition, salt content, and cation-exchange characteristics of the soils are needed, not only as a basis for determining cropping patterns, but also for planning capital expenditures for development. For example, the high salt and sodium contents of the soils in much of the Indus Delta region raise serious question concerning the economic potentials of these lands. Considerable further investigation is needed to determine the areas of fresh and saline underground water, and the chemical composition of the salt water. Much of the latter has a sufficiently low salt content so that it can be used for irrigation when diluted with fresh canal waters.

36. A plan for greatly increasing agricultural production is being devised by means of which technological possibilities can be brought into effective relationship with economic feasibilities and human capabilities. In the northern two-thirds of the Plain, the supply of irrigation water for actual consumptive use by plants can be doubled, in part by river regulation through surface storage, but chiefly by constructing a network of carefully-spaced tubewells to recover canal seepage and allow controlled mining of the underground water. The tubewells will also make it possible to leach the accumulated salts out of the soil and ultimately to eliminate waterlogging.

37. Yields per acre can be increased by providing more irrigation water, and water at the right time, by the use of fertilizer, by controlling plant diseases and pests, by the development and use of improved seed and crop varieties, and by the introduction of better cultivation practices. Each of these five production factors may increase yields 20 per cent when applied singly, but in combination they could

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1/ The following discussion is based on the work of the U.S. White House - Interior Panel on Waterlogging and Salinity in West Pakistan, undertaken in 1962.

give increases of 200 to 300 per cent. In order to integrate all the factors of production, it is necessary to concentrate their application in project areas of manageable size. Analysis of the hydrologic processes involved, and of the economics of fertilizer production, indicate that the project areas should contain about a million acres. If adequate capital and technical manpower can be made available, it should be possible to initiate development of a new million-acre project each year.

38. Linear programming analysis shows that the principal benefit from the tubewell water will come from the maximum possible expansion of the planted areas during the summer season in the most profitable crops.

39. Electric power for pumping water can be obtained either by hydroelectric development in the mountains and foothills of the north, or by thermal plants using natural gas. West Pakistan is fortunate in having fairly large reserves of natural gas, which can be used also as a source of nitrogenous fertilizer. With electricity, phosphate fertilizers can be made from imported raw material.

40. To attain momentum in increasing production, an optimal sequence of capital investment is essential. First expenditures should be for development of underground water and drainage, fertilizer plants, pest control facilities, training and organization of technicians, administrators, and field workers to assist the farmers, development of better plant varieties, and needed investigations. Later, roads and transportation facilities must be provided to haul a greatly increased volume of agricultural products to the cities and towns. Processing mills and textile factories will have to be built to utilize these products profitably. Still later, a farm machinery industry will be needed, and factories to produce consumer goods for the farmers will ultimately be required. Only a few conveyance channels to carry off salty waters in order to maintain a salt balance will be needed at first, but many of these relatively expensive structures must be built within about 20 years of the initial development.

41. In the northern two-thirds of the Plain, an initial capital investment of about Rs 260 to 285 an acre is needed in order to allow integrated use of the primary factors of production. Ultimate expenditure may be several times this amount. After full development, the maximum net increase of crop value in the northern area from additional water, fertilizer, plant protection, and presently existing better plant varieties, could be Rs 3.6 billion, equal to twice the average gross production during the last decade, excluding livestock.

42. All aspects of the program rest on vigorous education and agricultural extension efforts to guide the farmers in carrying out their part of the task, ample credit to make the farmers' participation possible, and efficient marketing and distribution facilities. Massive and determined effort, and continuing experimentation will be necessary to transmit new technical skills to very large numbers of desperately poor and illiterate farmers, and to create economic conditions in which they will be motivated to help themselves.

Some Common Problems of Resource Development

43. A few common problems of resource development in less developed countries may be listed here. Some are theoretical; some are practical. Research and experimentation offer the best avenues for dealing with them. The kinds of analysis suggested in this paper seem promising. These problems include:

---Improving the amount and quality of resource data, both scientific and

economic, and further testing of analytical methods so as to make the data more useful in planning.

---Determining a strategy of resource development in national economic growth. What are the main elements of such a strategy? What variables are critical for forward motion and how may they be manipulated? What sequence and combinations of industrial investment, workers' training, agricultural improvement, and occupational and regional shifts are called for in each country for the resource sectors?

---Interrelating more closely the food and raw material shortages in some countries with surpluses of production or capacity in others.

---Devising workable international arrangements for financing resource development, for market and price stabilization, and for technical aid in resource planning.

---Finding an effective division between public and private sectors with appropriate interrelating of the two. The line of division will, of course, vary from country to country according to its particular history and present situation.

---Appropriate safeguarding of the productiveness of basic resources, such as soil and water, and of the quality of the natural environment.

---Adjusting to the declining relative importance of agriculture and some other resource industries in national economies. This will involve a balancing of programs for raising agricultural efficiency (better farming practices, improved processing and marketing of crops, more machinery and power, better health and education, more credit) with programs of industrialization, principally in urban areas.

---Adopting cost-reducing technology in resource activities as rapidly as possible.

44. Within each country, and perhaps within each sub-national development region, an organizational means for resource development planning, at least for the coordination of such planning, will be beneficial. Some countries have such arrangements; others do not. Typically this will mean drawing together representatives from a number of departments or agencies of the government spanning the various natural resources of land and agriculture, forestry, fisheries, water and power, energy, minerals, and the like so that comprehensive and multiple purpose policies and plans may be worked out. In many countries, this may be done within or in conjunction with national and regional planning bodies. To begin with, data gathering and research in the resources field should be coordinated and given central attention.

45. Since common problems of resource policy-making, planning, and development are to be found in one form or another in virtually all less developed countries, and since the more developed countries will also have to take some part in solving them, frequently through the use of analytical techniques as described in this paper, there would appear to be much to be gained from a more concerted attack on them than has thus far been made. We suggest, therefore, that consideration be given to the establishment of a World Resources Development Institute with the following purposes:

a. To undertake, and stimulate others to undertake, scientific, technologic, statistical, and economic research on natural resources, especially as such research bears on policy and planning.

b. To foster exchange of information, and perhaps to establish a central library of knowledge.

c. To encourage the education and training of resource specialists through seminars, fellowships, exchanges of personnel, and the like, working in relation with existing universities and public and private institutes.

d. To build an international panel of resource specialists for technical aid in water, land, energy, and minerals, with emphasis on the planning of developments in these fields.

e. To cooperate with various groups concerned with resources, including other international agencies, national and sub-national organizations, and appropriate private groups.

46. Direction of such an institute could be by an international board of world leaders in the resources field, of scientists, engineers, planners, economists, administrators, and educators. Possibly the national academies of science or some similarly respected bodies could act as sponsors. Financing might come from participating countries or organizations, foundation grants, or from the United Nations or its specialized agencies concerned with resources. The institute could be a part of United Nations, or it could be outside UN but cooperating with UN and certain of its specialized agencies.

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TYPICAL PROBLEMS IN THE DEVELOPMENT OF MODERN POWER SUPPLY IN LESS DEVELOPED AREAS

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

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TYPICAL PROBLEMS IN THE DEVELOPMENT OF MODERN POWER SUPPLY IN LESS DEVELOPED AREAS

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(1) It is the purpose of this paper to describe, in terms of some specific areas concerning which the writer has personal and professional knowledge, the situation of electric power supply before and after major development efforts. In each case a new institution was established which undertook to expedite a process of change as one of its major functions. Of these institutions, each has a framework of major characteristics which is of interest. The specific problems with which these new agencies dealt are set forth, and the actual solutions that were adopted are stated. The present status of power supply and prospects for the future are also summarized.

(2) The cases include the areas served by the Tennessee Valley Authority (TVA); Greece, which is served by the Public Power Corporation (PPC); El Salvador, where increments of power supply are the responsibility of the Comision Ejecutiva Hidroelectrica del Rio Lempa (CEL); Puerto Rico, served by the Puerto Rico Water Resources Authority (PRWRA); and the Khuzestan region of Iran, where a modern power system is under development by the Khuzestan Water and Power Authority (KWPA).

(3) The final portion of the paper summarizes some conclusions, based upon the experience in these five areas, which are of potential significance in other areas facing somewhat similar problems in providing modern power supply for their homes, farms, commercial establishments and factories. Especially to be noted are the common elements in the individual solutions developed in each of the areas. These common elements may well be significant for other areas because they can be clearly identified in the five cases, and because in all five, modern electric power supply has been or is being achieved in areas where electric service had previously not met modern standards of adequacy, reliability, and reasonableness of cost.

THE CASES

The TVA Area

(4) In 1933, during the early days of the administration of President Roosevelt, the law was passed which established the Tennessee Valley Authority. The TVA Act was the conclusion of a series of preceding but unsuccessful efforts to establish an agency for development of the resources of the Tennessee River and the region through which it flows. Key policies for electric power included:

(a) The TVA power system was to be self-supporting and self-liquidating. It was to be able to use its revenues for power system purposes.

(b) Power was to bear its share of the costs of facilities used also for TVA's primary purposes of flood control and navigation.

(c) TVA power was to be conceived as being available primarily for the benefit of the people of the section as a whole with preference for the domestic and rural consumers, and the sale of power to industry was to be a secondary purpose, primarily to secure a high system load factor and to improve revenue returns. TVA was to seek the application of electric power to the fuller and better balanced development of the resources of the region.

(d) The Act clearly implied that TVA was to sell power primarily on a wholesale basis, giving preference to public and cooperative agencies not doing business for a profit.

(e) In lieu of taxation, TVA was to pay a percentage of its revenues from the sale of power to the states within which it operates, a part of these payments to be paid to local agencies of government which suffered loss of tax revenues due to TVA's acquisition of properties formerly in private ownership. This percentage is now 5%.

(5) Some of TVA's other key policies applying to all of its operations included:

(a) It was to have much of the flexibility of a private enterprise. For example, its employees were to be appointed without any political tests and were to be employed under a merit system with salary classification established by TVA, independent of the U.S. Civil Service system.

(b) Its Board was to consist of three members, chosen by the President with the consent of the Senate, responsible to the President and with staggered terms, ultimately nine years each to assure continuity through changes in national administrations.

(c) Its accounts were to be kept in accordance with the Federal Power Commission system of accounts.

(d) It was given the power of eminent domain.

(e) It was to have authority to take necessary action to carry out these policies.

(6) By 1933, in the Tennessee Valley region power supply was, in most cases, available from large central station sources only in the major centers of population. There were a number of isolated municipal systems, usually depending on diesel-electric generators. Rural electrification extended to only 3% of the farms. Average residential use was 600 kwh per year, about the same as the national average. Total regional electrical energy requirements were about 1-1/2 billion kwh. In hearings about TVA legislation and appropriations, representatives of existing power systems testified that the future market for power in the region was limited and the capacity planned for installation by TVA was not required.

(7) One of TVA's statutory tasks was to develop a comprehensive plan for integrated development of the Tennessee River and its tributaries. This was completed in 1936, and guided future development.

(8) TVA, located in an area which was predominantly agricultural, began its operations with a labor force in which modern industrial skills were limited. Training of foremen, accountants, managers and skilled workers was an essential element of its early program.

(9) In order to develop the region's power supply on the most economical basis, an integrated generation, transmission and distribution system was required. This was accomplished largely through the acquisition by TVA of the existing bulk supply (generation and transmission) facilities, and through acquisition of the existing distribution facilities by local public agencies, and by cooperatives, which became the distributors of TVA power. Acquisitions were negotiated at prices agreed upon between buyers and sellers. The acquisition program was completed in 1945 and included properties for which sales prices totalled about $125 million. The facilities thus acquired were interconnected with newly constructed facilities owned by TVA and by the municipal and cooperative distributors of TVA power.

(10) TVA's financing has come primarily from direct Congressional appropriations and from its own earnings. The early acquisition program was financed in part by the issuance of bonds which were purchased by the U. S. Treasury. Within the past few years, TVA has been authorized, by amendment of the Act, to issue up to $750. million

in revenue bonds for sale to the public to finance the further expansion of its power system within its existing service area. Some $100 million of such bonds have since been issued.

(11) TVA now supplies power throughout an area of some 80,000 square miles, with a population of some 5 million and with about 1-1/2 million consumers of electricity. Total requirements for electrical energy have reached 60 billion kwh, or about 40 times their level of 30 years ago. Almost half of these requirements are for national defense purposes, including atomic energy. Ninety-eight percent of the farms in the region have electric service. A high proportion of all new homes are heated with electricity. Average residential consumption is almost 10,000 kwh per consumer per year, or about 2-1/2 times the national average. The average rate for this service in the TVA area is a little less than one cent per kwh, or about 40% of the national average. With total system generating capacity of over 12 million kw, TVA ranks as one of the largest integrated power systems in the world. Having practically exhausted the economical hydroelectric power in its region, it will, in the future, depend largely upon thermal sources to meet its continued growth requirements. It now uses about 20 million tons of coal per year. TVA has a cooperative understanding with the Atomic Energy Commission for work on an experimental gas-cooled reactor for power purposes.

Greece

(12) When fighting ceased in Greece in 1949, it was recognized that electric power supply should have a high priority in the work of reconstruction and expansion which needed to be done. A survey of power requirements and some of the principal power resources was made by a firm of consulting engineers financed by U.S. aid funds. Following the completion of this survey, the U.S. and Greek Governments agreed that electric power development would be one of the major programs during the period of reconstruction, to be financed in part by Marshall Plan funds, in part by Italian reparations, and in part by Greed resources.

(13) In 1950, the Greek Parliament enacted legislation to establish the PPC to own and operate the new power system, a private company being engaged to manage the affairs of the PPC, to train its personnel, and to supervise the contractors engaged in developing the new power facilities.

(14) Before PPC came into being, the only modern electric system in Greece, with electricity in reasonably adequate supply at reasonable cost, was that belonging to the Athens-Piraeus Electricity Company (APECO), largely owned by British interests, and serving the metropolitan area of the capital. In the second city of Greece, Salonika, the urban electric system was partly alternating and partly direct current, and service was inadequate and costly. In 1950, a portion of that city's power supply came from small naval vessels moored at the quay and connected to the electric distribution system. Salonika's entire system had to be extensively rebuilt and expanded. A few other urban centers had electric service but only on an inadequate and high-cost basis.

(15) By 1954-55, PPC completed the first stage of a new nationwide system which included three hydroelectric plants, a large thermal-electric station, a 150 kv transmission system, and primary distribution networks at 15 kv. Service began to be extended to the villages of Greece. Inadequate urban systems were replaced. Further power expansion was undertaken by PPC after the completion of the first program. In 1960, PPC acquired the APECO system. Today, PPC is responsible for power supply throughout Greece, including the Greek islands. Only a few local systems remain in their previous ownership, the largest being that of Patras.

(16) In 1950, total generating capacity in Greece was less than 200,000 kw. By 1955, with the completion of the initial expansion program financed in part by U. S. aid, total capacity had doubled. The second expansion program now completed or under construction will bring the total generating capacity to about a million kw, or over

five times the capacity in 1950. Further substantial expansion of the PPC system is now under design. Since 1955, development has been largely financed by earnings and by internal and external loans and equipment credits.

(17) PPC's initial policies were set forth in its original enabling legislation, adopted in 1950, and in its subsequent amendments. It was to be an autonomous agency, responsible to the Greek State through the Ministry of Industry. Members of the Board of Directors were to be appointed by the Government on the Minister's recommendation. The members of the seven- (later changed to nine-) man Board were to have five-year terms of office, for staggered periods. Power was to be supplied by PPC on a basis which would assure its availability at the cheapest possible cost to the consumer, while PPC covered its costs of service. There was to be no unreasonable discrimination in the sale of power between regions of the country or between customers of the same class. For its key personnel, PPC was to be exempt from Civil Service rules and regulations. It was to be able to act as though it were a commercial enterprise. Its accounts were to be kept in accordance with best modern public utility accounting practice. There was to be a Representative Assembly, consisting of representatives of government, labor, banks, industry, the principal municipalities, professional societies and trade associations, etc., with responsibility for general annual or special review of PPC's operations.

(18) It was intended that the resources used by PPC for power supply were to consist primarily of those indigenous to Greece, water power and lignite. Before 1950, except for emergency use in war-time, these resources were practically undeveloped. PPC has been instrumental since that time in opening up a large lignite deposit at Aliveri, on the island of Euboea, to fuel a power plant at that location, and a very large deposit at Ptolemais in the north, to fuel another power plant and to provide raw material for industrial development. A 150 kv interconnection has been established with Yugoslavia.

(19) Most of the villages on the mainland of Greece and many on the islands have been electrified under the PPC program. A standard set of rate schedules are applied throughout the PPC service area, including the islands, except in the capital region, where APECO's rate structure has been maintained by PPC, the new owner. The levels of average rates for the various classes of consumers are not significantly different in these two parts of the PPC territory.

(20) PPC's rate of growth has averaged 10 to 12% per year, the growth being more rapid outside than inside the capital area. Total use of electrical energy was 538 million kwh in 1950, of which 451 million kwh were used in the Athens-Piraeus area. Total use in 1961 was 2156 million kwh, of which 1445 million were used in the capital area. Plans for new power sources are under active consideration to meet future needs including the provision of a new large thermal power station in the Peloponnesus at Megalopolis, which will tap large lignite deposits in that area.

(21) The hydroelectric development of the Acheloos River in Western Greece, which is to be interconnected with the national network, is the base for quite an industrial complex, including an aluminum smelter being erected by a combination of French and American interests.

(22) Since 1955, PPC has been managed and operated by its Greek organization. The Ebasco management group was entirely withdrawn after expiration of its original five-year contract, and consulting services have since been of a more technical and traditional character.

El Salvador

(23) El Salvador, a Central American republic, has a population of about 2-1/2 million, and an area of some 8,000 square miles.

(24) In 1945-46, it was decided by the Government that a large increment of electric power was needed, and a hydroelectric development at Chorrera del Guayabo, on the Lempa River, with associated transmission facilities, was undertaken, after detailed

investigations. In 1948, the IBRD undertook the financing of the foreign exchange portion of the costs of this project. The consulting engineers were responsible for design and supervision of the construction of the project. The dam is now known as the Fifth of November.

(25) Before 1948, the only fairly large electric system was that in the capital, San Salvador,(CAESS), which also served the surrounding towns. It is owned by a Canadian group. The same group owns the much smaller system serving San Miguel, in the eastern portion of the country. Another smaller system served Santa Ana in the west, and there were small scattered systems in other towns, most of them privately-owned. In 1953, total generating capacity in the country was about 20,000 kw.

(26) With the decision to move ahead with the Lempa development, the Government of El Salvador established, through legislation and executive action, CEL, a public entity owned by the Government. Initially established by decree to make the necessary preliminary studies and investigations, CEL was later (1948) given a legislative charter. CEL had a seven-man board of directors with staggered four-year terms, four of whom were designated as individuals by the Government (acting through four cabinet offices) and of the other three, one was selected by the banks, one from a list provided jointly by the local agricultural, commercial and industrial associations, and one by the local bondholders (other than the Government). For each board member, an alternate was appointed by the same procedure.

(27) The Lempa project includes four generating units of 15,000 kw each, two of which were installed by 1954, one in 1957, and the fourth in 1961. A second hydro project, Guajoyo, is almost completed. It will control and utilize the outflow from Lake Guija, which lies athwart the border of El Salvador and Guatemala.

(28) CEL's legislative charter gives it irrigation as well as power responsibilities. It is exempt from civil service rules and regulations. It is to operate as an autonomous non-profit public service enterprise. It is directed to give preference to the sale of power at wholesale to public or private agencies. Rates and charges are to be reasonable and adequate to cover costs, including debt service. CEL can borrow money in its own name, with Government approval. It has the right of eminent domain. Employees are to be chosen solely on the basis of merit and efficiency, without any political test. CEL and its contractors are exempt from customs duties, for imports necessary for its work, and from local taxation.

(29) In 1953-54, CEL negotiated a wholesale power contract with CAESS, which specified wholesale and retail rates, and the maximum rate of return on investment which the company was to be permitted. This contract gives CEL the opportunity to assure that the benefits from the availability of CEL power are shared on a reasonable basis between the consumers and the owners of the company. Since return has recently exceeded the contractual allowance, retail rates were reduced in 1961.

(30) Since 1953, the year before the Fifth of November project began operating, generating capacity in El Salvador has been quadrupled and requirements have risen equally rapidly. CEL now supplies over four-fifths of the country's electrical energy needs. Over 80,000 consumers are using CEL power. Service has been extended to most of the main urban centers from the CEL system, and contracts similar to that with CAESS have been negotiated with the distributors in other areas.

Puerto Rico

(31) Puerto Rico, an island about a thousand miles south and east of Miami, Florida, bounded by the Atlantic and the Caribbean, has an area of about 3500 square miles. Its population is approaching 2,500,000. It is a Commonwealth within the United States, with a unique constitution established in 1952 by compact.

(32) In 1942, legislation was enacted by the Puerto Rican territorial legislature establishing the PRWRA, an entity owned by the people of Puerto Rico. Its purposes were to produce and supply electricity, which it now does throughout the island, being responsible for serving all but a few of the ultimate consumers. It also had some irrigation responsibilities.

(33) In 1942, PRWRA acquired the properties of the Canadian-owned company serving the San Juan capital area, and of the company serving the third largest urban center, Mayaguez. The privately-owned system serving Ponce, the second largest town, had been acquired previously by the public agency which was the predecessor of PRWRA.

(34) In 1941, the year before PRWRA was established, the total production of electrical energy for public use in Puerto Rico was about 192 million kwh; and 113,000 consumers were being served. Twenty years later, in 1961, total production was about 2,300,000,000 kwh, or a multiplication in two decades by twelve times. In 1961, over 400,000 consumers received service.

(35) The legislative charter of PRWRA provided for the establishment of a three-man Board of Directors, the members to serve ex-officio, including the Governor, who was the Chairman of the Board, and two members of his cabinet. Responsibility for managing the affairs of the agency was placed in the Executive Director, who was to be chosen by the Board. The PRWRA Act provides that charges for electric service fixed by PRWRA shall be reasonable and adequate to cover costs, including obligations to the holders of the agency's bonds. It may borrow money in its own name and pledge its revenues for its debt service. It appoints its own officers and employees and fixes their rates of compensation. It has the power of eminent domain, in the name of the people of Puerto Rico. In lieu of all other taxes, PRWRA pays 5% of its power revenues to the Commonwealth Treasury, and 6% is divided among the municipalities within which it operates.

(36) The PRWRA system was in part acquired from its predecessor public agency (which was called Utilization of Water Resources, an office of the Insular Government), in part built with grants from the United States, and in part acquired or constructed with funds obtained through the sale of revenue bonds on the New York market. The most recent bond sale, in 1962, was in the amount of $22,000,000., at an average annual interest rate of about 3.6%.

(37) About 110,000 kw of PRWRA's generating capacity is hydro-electric. Since practically all of the economical hydro sites have been utilized, increments since 1956 have been thermal-electric. The thermal plants are fueled with oil, largely consisting of the heavy residuals available from the two oil refineries now in operation on the island, one in the north and one in the south. Total PRWRA generating capacity at June 30, 1962 was about 700,000 kw.

(38) The expansion of rural electrification throughout the rather mountainous terrain has been rapid. The work is carried out under a program financed by the Rural Electrification Administration of the U. S. Department of Agriculture which buys some of PRWRA's bonds each year, with an annual interest cost of 2%. Rural electrification is also supported by annual payment from the Commonwealth Treasury, in order to enhance its economic feasibility for PRWRA.

(39) PRWRA is staffed almost 100% by Puerto Ricans. Many have had training in the continental U.S. Consulting engineers were retained for consultation and advice, especially in the fields of power economics and management policy. PRWRA, in cooperation with the U.S. Atomic Energy Commission, is constructing a 16,000 kw nuclear power plant (BONUS) in the western portion of the island. This plant will have the advanced feature of integral nuclear superheat with a boiling water reactor.

(40) Puerto Rico has for the past ten years been engaged in what has become known as Operation Bootstrap, an intensive program of economic development. As a result, several hundred new industrial enterprises have been established on the island, transportation and communication have been improved, modern water supply and sewerage systems have been built and the standard of living has been significantly raised. Income from industrial activity now exceeds by a significant margin agricultural income, which had been the predominant income source throughout the island's recent history. One of the prominent factors in support of this development program has been the availability, thru PRWRA, of an adequate supply of electric power at reasonable cost. PRWRA's rates for electricity are comparable with those of electric utilities serving the Atlantic seaboard

of the U. S. They lie roughly in the middle of the range of these schedules between the high and low extremes. PRWRA is now the second largest non-Federal publicly-owned electric system in the United States and its territories.

The Khuzestan Region of Iran

(41) In southwestern Iran, bordering the head of the Persian Gulf, lies the region known as Khuzestan. It comprises an area of about 58,000 square miles, with a population of about 2-1/2 million. It includes a broad desert plain, very flat, extending from the Gulf to the Zagros or Bakhtiari Mountains to the north and east. In the foothills of these mountains lie most of the producing oil fields of Iran.

(42) The plain is drained by five rivers. On one of these, the Dez, there is rising toward early completion a thin arch concrete dam, sixth highest in the world, which will have initial generating capacity, in two units, of 130,000 kw, and ultimately an eight-unit capacity of 520,000 kw. It will be placed in operation in early 1963.

(43) In 1956, a U.S. private firm was asked by the Government of Iran to assist in devising a plan for the economic development of Khuzestan, the region which, for many centuries, was the source of the economic power of ancient Persia. After receiving and approving the recommendations, the Government asked the firm to assume responsibility for helping to execute them. The firm completed and delivered to Plan Organization a unified program for development of Khuzestan. This program included a total of some 6 million kilowatts of hydroelectric capacity in fourteen projects, and water supply for a million hectares of agricultural land.

(44) In 1957-58, electric power supply in Khuzestan was primitive. The only partial exception was Abadan, where the oil companies have one of the largest of the world's refineries. There the companies were supplying their own employees, which constitute the majority of the electricity consumers of the town. In the other urban centers, there were various combinations of public and private systems, with no control or regulation. Service was unreliable and otherwise inadequate, connection charges were exhorbitant, and rates were not such as to encourage the use of the service.

(45) As part of the development program, in 1959, a 132-kv transmission line was placed in service between Abadan and Ahwaz, the capital of Khuzestan province. This was used to deliver to Ahwaz power purchased from the oil companies at Abadan. The Ahwaz distribution system was rehabilitated and expanded. The number of consumers served has grown from 7,000 in 1958 to 18,000 in June, 1962. Included in the Ahwaz service area are about ten surrounding villages previously without electric service of any kind. Power demand on the Ahwaz system quadrupled in three years.

(46) As a basis for system rehabilitation and expansion in Ahwaz, D&R for the Government acquired the privately-owned system in the town and integrated it with the municipal system under the ownership of the newly-formed company owned by the municipality. D&R is assisting the Government in managing the affairs of this company and training its organization. A wholesale power contract which establishes retail rates and terms of sale was made effective. A similar series of steps is in progress in the four other urban centers of Khuzestan to which Dez power will initially be made available.

(47) As part of the plan, in 1960, the Government established the Khuzestan Water and Power Authority to carry on the development program, KWPA has its own legislative charter, which places primary responsibility for its affairs upon the Deputy Prime Minister and Head of the Government's Plan Organization. The Deputy Prime Minister can delegate his powers to the Managing Director of KWPA whom he also recommends for appointment by the Prime Minister. Such a delegation has been made. KWPA, under its charter, may use its revenues to finance its operations, may appoint its own officers and employees and fix the levels of their compensation. It establishes rates for the sale of electricity and charges for irrigation water. It maintains its own system of accounts, and, while wholly-owned by the Government, it is intended to have sufficient autonomy to operate as an independent enterprise.

KWPA is to conduct development operations for irrigation and power associated with the waters of the five Khuzestan rivers.

(48) KWPA has accepted full responsibility for power operations and for general services. In power operations, the Hydroelectric Power Commission of Ontario helps to operate and maintain the Dez hydroelectric project and to train a staff of Iranians later to assume these responsibilities. The Ontario Hydro group serves as part of the organization of KWPA's Power Division, which is headed by an Iranian engineer. Reporting to him is the Technical Director of the Power Division, through whom the various elements of the organization now report. By 1965, it is anticipated that the power operations of KWPA can be entirely handled by its Iranian organization, with the training it will have received.

(49) The Government of Iran negotiated with the International Bank for Reconstruction and Development, which agreed to lend $42 million to Iran for the Khuzestan program. The balance of the funds required are being supplied by Plan Organization, from Iran's oil revenues. The total cost of the present KWPA program is estimated at $150 million. Included are Dez Dam, transmission lines and substations, a pilot irrigation project, a sugar cane plantation and factory, and rehabilitation and expansion of five electric distribution systems in and near the principal load centers. The loan agreement with IBRD includes provisions for maintenance of rate levels for power and the establishment of KWPA.

(50) With the availability, for the first time, of modern reliable electric service, in adequate supply and at reasonable cost, power requirements in Khuzestan have been demonstrated to be capable of rapid growth. The third Dez generating unit is scheduled for installation in 1965-66, and will be needed by then. The fourth is scheduled for 1968. Its actual date of installation can be adjusted to meet any changes from the rate of growth of power needs which is now foreseen.

CONCLUSIONS

(51) Securing modern electric power supply for a particular less-developed area requires the solution of many problems which are peculiar to that area. The technical nature of the facilities to be provided, the type of primary energy sources which are available, the existing power systems and their integration, these and more need to be approached for each such area so that their solutions can be tailored to meet the area's needs. In the five cases which have been reviewed, however, there were some problems of significance for the solution of which common avenues were pursued. These common avenues may be of special interest as holding promise for other less-developed areas. These problems and their solutions were as follows.

(52) The problem: To establish an agency with power to exercise sufficient responsibility to carry out the necessary work. No private agency has accomplished this, and no existing agency of Government is set up with the necessary skills and authority. The solution: By formal governmental action, usually including actual legislation, to establish key policies and new institutions, separate from the regular administrative departments, although by various methods, responsible to and through the existing structure of Government at some fixed point. There are some especially significant policies for these institutions which appear with frequency:

(a) They resemble the corporate rather than the governmental form.
(b) They are intended to be largely autonomous.
(c) They are to have wide flexibility of action and decision.
(d) They are to be largely independent of the regular civil service.
(e) Accountability is assured by prescription of modern accounting practices and regular reporting.
(f) Administration and personnel are intended to be non-political.
(g) They are intended to be financially self-supporting, and to charge the users of their services enough to cover their costs.

(h) They are to be non-profit.

(i) They are to be exempt from regular taxation, with provision in some cases for payments in lieu of taxes under a specified formula. Except for such payments, none of the agencies can serve as a channel for contributions by electric consumers to the general funds of the owning government.

(53) The problem: To finance the cost of construction of the modern electricity supply facilities. The solution: With initial contributions from the sponsor or owning Government of cash and property, the new institution finances its costs through (a) its income, (b) its own internal and external borrowings, and (c) through borrowing made or guaranteed by the sponsor Government. In each case, the sponsor Government is in the position of the owner of the equity in the new institution, the new institution being responsible directly or indirectly for defraying the debt service costs. The return on the owner's equity is not ordinarily to be in cash terms, but in terms of benefit to the general welfare.

(54) The problem: How can the necessary higher skills be acquired rapidly in order to utilize and apply the advanced technologies involved in providing and operating a modern electric power system? The solution: Each case, in its own way, has involved the importation into a geographical area of management, engineering, and labor skills not indigenous to the area. Training programs are then depended upon to bridge the gap between (a) the early organization using foreign skills and (b) the ultimate organization made up largely of local people. Continuing availability of high-level technical and management assistance is obtained through appropriate contractual arrangements.

(55) The problem: How to integrate existing electric systems into the newly constructed system in such a way as to make optimum use of existing properties and organizations, while moving ahead toward the integrated system with its inherent economies. The solution: Most common among the five cases has been the negotiated purchase of existing privately-owned systems, and the absorption of existing publicly-owned systems, if any, into the new one. Existing organizations are absorbed, to the extent that they can be useful to the new institution, either directly or by re-training. Wholesale power contracts are also used as the vehicles through which the new institution's policies are adopted by local agencies distributing power supplied from the new system. They control retail rates and customer service and accounting policies. This is, of course, not necessary in cases such as PPC and PRWRA, which serve all, or practically all, ultimate consumers in their service areas.

(56) The problem: How to develop internal and external sources of financing for the large investments necessary to supplement its own and its owning Government's resources to provide for a modern electricity supply system? The solution: In each case the new institution has the power to borrow money in its own name, and has used this power or the borrowing power of its owning Government to secure a portion of the funds required. In each case, also, the new institution has the right to dispose of its revenues for power purposes. The electric power business can be depended upon to yield revenues adequate to cover its costs. Investors will be willing to advance funds for it at reasonable cost if they are assured that the institutional arrangements will preserve the financial integrity of the business; if, in other words, the credit of the new institution is established and maintained, if it is proven as a "good risk". The private capital markets, within the country or in the outside world are depended upon in some of the cases, others have so far limited themselves to public agencies, still others have used a combination of private and public sources. Supplier credits have also been utilized.

(57) The problem: How can the magnitude of future requirements be measured, in order to determine goals for the development of the new electric system? The solution: The records of actual growth for the five cases throw some light on this question. In each case there was a clean break from past records, when the institutions went into operation. With new objectives as to adequacy of electricity supply, levels of rates, etc., the increases in level of use were far greater than many expected. The most important step was the establishment and implementation of the new objectives. Then, the provision of new capacity to meet changing future needs could be geared to provide adequate margins. If

growth is less rapid than expected, planned expansion can be postponed, if growth is more rapid new facilities can be accelerated. Plans should be made for power system development which are geared to probable future levels of needs with certain specified timing assumptions. Changes of timing can then readily be accomplished as the facts of future requirements and their rates of growth become available. Initial market predictions can take into consideration basic economic considerations such as population and its growth, and specific industrial development possibilities, as well as experience in other areas when adequate power supply becomes available. The experience in the five cases shows that high rates of growth are probable, and that doubling every five years or so can be maintained for extended periods.

(58) The problem: Determining what role in electric power supply should be played by indigenous primary energy sources. The solution: Emphasis was first placed in all cases upon development of indigenous energy sources, especially water power. Then, as requirements continue to increase, local coal and oil refinery product resources enter the energy supply for the power system. Foreign exchange needs for oil purchases place a premium on the use of other primary sources which may encourage their development, even at somewhat higher economic cost. However, the premium thus paid by consumers of electricity as their contribution toward preserving their nation's foreign exchange balances should be continuously examined with a critical eye to assure that it does not become so large as to interfere with the accomplishment of the objectives of power system development. Electricity is a highly flexible form of energy. Technology now has advanced to the point that it can be produced economically through the use of a wide range of primary sources, including, in addition to water power, coal of practically all grades, natural gas, and many grades of petroleum products, ranging from crude oil, through light products to residual fuel oil (Bunker C) and even to refinery pitch which is used by PRWRA directly from the refinery and which is quite economical.

(59) With the establishment of public sources of financing such as the IBRD and its affiliates, International Finance Corporation and International Development Agency, the Inter-American Development Bank, the U. S. Agency for International Development and its counterparts among other Western nations, opportunities have greatly multiplied for less developed areas to secure assistance in financing modern electric power systems. Consulting and advisory services are widely offered by private and public agencies. And experience in other areas such as the five cases described here is accumulating rapidly.

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BASIC PRINCIPLES OF ANY GENERAL PLAN FOR DEVELOPING NATURAL RESOURCES IN EMERGING COUNTRIES

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Papers have been contributed to the United Nations Conference on the Application of Science and Technology for the Benefit of the Less Developed Areas as working papers for that Conference. They are published as presented by the contributors, and the contents and the views expressed are those of the contributors. (See notes overleaf.)

NOTES

1. Papers selected for inclusion in General Sessions will be available at the Conference in the following official languages of the United Nations: English, French, Russian and Spanish.

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BASIC PRINCIPLES OF ANY GENERAL PLAN FOR DEVELOPING NATURAL RESOURCES IN EMERGING COUNTRIES.

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1. INTRODUCTION : The limitations of human action set by the natural environment.

a) In this century, men grow increasingly aware of the limits which the physical factors of their environment set to their action. Surprisingly, this awareness springs from their increasingly powerful techniques, more accurate forecasts and better knowledge of the natural phenomena which they use or are subjected to. With greater means at their disposal, men are venturing forth to larger and more daring undertakings. Their daring, however, is tempered by an increasing caution. For in the past, when men failed to see and appreciate certain factors or deliberately ignored them in making their plans, they have been taught some terrible lessons.

b) We have too often witnessed human entreprises foundering upon some unpredictable turn of the elements. Perturbations of the natural environment can produce its destruction, disrupt its balance, set off irréversible processes and sometimes even catastrophes. In such entreprises as those involving the water cycle, the transformation of soils, the biosociological equilibrium of animal or vegetable species, some at first beneficial actions have ultimately led to disastrous results which were most serious because least expected.

c) In a world grown too small for men to escape from the earth they have exhausted, in a community of nations where promises must increasingly be kept, carelessness is no longer tolerable in using means which may dangerously affect the life and well-being of men.

d) It is therefore imperative, when developing natural resources, to dispel the false hopes raised by Man's belief in his unlimited technical skill. We must recognize and understand the elements governing the environment in which we intend to act and we must take them as guidance for our plans. Only thus can we make promises we are able to keep, benefit most rationally from our efforts and avoid subsequent disappointments and misfortunes.

e) Any plan of action must have a scientific basis. It includes :

i) first phase : a preliminary survey to list the problems involved and marshal them for careful examination. This first phase is rounded off by the establishment of a general program.

ii) second phase : a thorough study which will provide the experimental data for a down-to-earth and detailed program.

2. FIRST PHASE : The preliminary survey and its interdisciplinary nature.

a) The inventory with which the preliminary survey commence is not merely the listing of known resources or adding to that list. Its scope must be far wider. It must include all factors likely to affect the development program. These factors may occur in scientific fields far removed from that in which action will be taken and it will thus be advisable to start with an overall scientific examination of the environment. Such an examination will cover several important scientific disciplines. Their order of precedence appears be as follows :

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i) firstly physical and physiographical data, the climate in particular, are obtained through the various branches of geophysics, through geology, soil science, geodesy, ...

ii) then biological data, provided by specialized branches of zoology, botany, medical sciences, agronomy and connected fields, ...

iii) and lastly data pertaining to man, from medical science, ethnology, sociology, ...

b) Once this inventory has been drawn up, it will be possible to organize the collection of still missing data according to a priority list to which we shall come back later. It should be pointed out that no economic data are mentioned above because these are generally not premises, but results of the influence of environmental conditions and factors on the technical aspects of each development project. Contrary to some still frequently heard opinions there is thus no urgent need to collect economic data. It would be out of place for instance to estimate the cost price for a new agricultural produce in a preliminary study and thus influence future plans. For at that stage it has not even been established yet what measures should be taken for the new venture, nor has it been calculated to what extent this new activity would transform the land.

c) If one accepts the principle that a preliminary survey is required before embarking upon detailed programs, it goes without saying that no attempt at forecasting results should be made at that stage. Experience has shown how serious the consequences of imperfect forecasts can be which fail to take proper account of some of the natural factors of the problem. Examples come to mind : the destruction of soil through cotton crops in the United States, the failure of the Ground-Nut Scheme in East Africa, etc.

3. FIRST PHASE : The lay-out of the preliminary survey.

a) Since several scientific disciplines are involved, the first survey work runs the immediate risk of scattering efforts and losing sight of its aim. Whereas the viewpoints of many sciences must be sufficiently well represented if nothing essential is to be forgotten, the several fields of investigation must nevertheless be restricted and research directed towards gathering knowledge that is truly necessary to the plan of action. In other words, research needs order, coordination and direction. It is advisable to choose a coordinator from a centrally-placed scientific discipline. For such a central discipline is the hub around which research in other disciplines develops.

b) This central discipline must be chosen with care and according to the nature and importance of the problem. As we are here dealing with the development of natural resources, it seems that the focus to choose in most cases should be the "physics and chemistry of the natural environment". This choice arises from two considerations :

i) A reason of principle : this fields embraces the various branches of geophysics, of geology and of soil science ; it provides information on inescapable matters which are to a large extent beyond human control. If such physical and chemical data are available, the other sciences concerned with the problem can better guide their research.

ii) A parctical reason : those who deal with the physics of the natutal environment, and most particularly climatologists and hydrologists, are generally best able to encompass the wealth of subjects to be studied. Their work has accustomed them to collaborate in agronomical, biological, sociological, medical, industrial and economic studies. This does not mean to say that they are competent in these specialized fields, but they are aware of the links between the various sciences.

4. FIRST PHASE : Scope and organization of the preliminary survey.

a) As described earlier, the team will make an inventory of known resources and also of the information required for proper assessment before embarking upon detailed planning. The team will therefore organize the systematic collection of missing data. This requires two steps :

i) priorities to be established in the search for information. First place will usually be given to four fields at once, where information is always indispensible and sometimes urgent : map, climate, water cycle, soils. Second priority will be given to data on mineral deposits and plant and animal resources. Third come data on population, roads of access and transport, etc.

ii) the collection of data. This means observing, measuring, experimenting, then applying calculations and reasoning to results obtained through observation and experiment. Maps are produced, statistics compiled, empirical laws uncovered ; figures are found to measure parameters which need to be taken into consideration when the general plan is set up. It might be useful to recall that this concerns only essential data to be quickly obtained during the course of the preliminary survey. Such a general prospection aims merely at defining the order of magnitude of the factors involved ; a few teams of experienced specialists and a minimum scientific equipment are sufficient for this purpose.

B) After completing the inventory by field work and the preparation of the results, the team for the preliminary survey will terminate its work by carrying out two further tasks :

i) the team will take part in the setting up of the general plan for the development of natural resources, i.e. in the selection of desirable and at the same time feasible undertakings. This plan consists of a number of specific projects, each of which will probably comprise a program of action and a thorough program of study. These two programs are to be carried out simultaneously.

ii) it will further establish these programs of study for specific projects, group requirements from various projects when they concern the same scientific discipline, prepare the organization of research teams and laboratories if required, establish observation networks or posts, experimental stations, etc.

c) Let us take an example to illustrate this last-named task and let us suppose that a preliminary survey has led to the decision to carry out the two following projects in a little-developed tropical country : 1) a dam on a large river for the generation of electricity and regulation of the water supply for agricultural and cattle-raising pupeses ; 2) the introduction of a new agricultural crop in the region that has thus been hydrologically improved. These decisions have been made on the strength of the preliminary survey which lasted 15 months, let us say, and produced a sufficient amount of information on topography, on the climatic and hydrological conditions of the region, on the soils and the minerals that might be worked thanks to the electric energy thus produced. Each project will have a program which fixes the successive stages of implementation. The work in each of these stages will require far more precise and detailed knowledge than that provided by the preliminary survey.

i) The first project - the dam - will require local topographical and geophysical surveys, geological prospections and borings. When the actual construction starts, there will be problems of diseases and pests eradication, necessitating knowledge on microclimates ; problems of increasing local food crops for the workers, requiring information on climate and soils, etc. This data will have to be collected carefully,

once only. On the other hand, it will be necessary to observe or measure for a good many years, if not permanently, a number of factors which will be used in the later phases of building and operation : rainfall data and the variations of each term of the water-balance in the catchment area, data on erosion and soil transformation, statistics on storms and lightning in relation with power-line protection, etc.

ii) The second project - the new crop - will need good land surveys, levelling, detailed and careful soil prospection, botanical and zoological studies, entomological inventory and a good knowledge of microclimates, etc., all information required only once. In addition, continuous observation of climatological and hydrological elements, as well, as an extensive study of parasites and viruses which may affect the crop or the population producing it, will have to be on a permanent basis and undertaken right from the start of the project.

iii) Thus, the two projects require a number of observations and experiments in various scientific fields and the task of meeting these temporary or permanent requirements will be given to scientific or technical units. These units are embryos of future services : Map, Geological, Geophysical, Hydrological, Medical, Agricultural Services ; their initial organization is the job of the people taking part in the preliminary survey and the units should start operating as soon as the projects get under way. We come now to the second phase of the plan.

5. SECOND PHASE : Specific studies.

a) Having set up scientific or technical units specialized in certain fields does not imply that these groups are going to develop independently of each other. An efficient coordination remains indispensable ; it should do more than ensuring simultaneous operation. A constant watch must be kept upon the progress in each field and mutual help between lines of research must be encouraged. Here are a few examples, all from the field of "physics of the environment".

i) Climate and soil, considered in relation to water resources, are important for widely different subjects such as : drinkable and industrial waters, irrigation, agronomy and animal husbandry, agricultural engineering, inland navigation, hydroelectric plants, soil conservation, etc. The same men, the same methods and equipment, can supply climatological, hydrological or soil data relevant to these problems, provided that the requirements are coordinated and that the observations, the laboratory experiments and the processing of the data have been adequately organized. To achieve this, a close cooperation between technical men in these various fields of activity is necessary.

ii) Climate, considered in relation to medical and sociological problems, affords quite another set of connections with public and industrial health, town and country planning, architecture, pests eradication, work organization, etc. The necessity for coordination and interdisciplinary cooperation is again apparent, as it is in the further examples.

iii) Meteorological forecasting in relation to air navigation, agriculture and a number of industries.

iiii) Geophysical prospecting and geology in relation to minning and civil engineering.

iiiii) Special subjects in Geophysics, in view of their applications, such as : ionospheric studies for telecommunications, research in non-conventional sources of energy (wind, radiation, tides), artificial weather modifications, (induced rain, control of lake evaporation, fog dissipation, etc). Such subjects, undertaken with a view to practical applications can succed only if an intelligent collaboration is maintained between the various fields concerned.

b) The kind of collaboration mentioned above is seldom obtained when technical assistance teams are recruited and set up separately for each project by different agencies, even when there is some high administrative coordination.

The sure result of this unfortunate and current custom is, to begin with, an inefficient use of the financial means. But worse still is the overlapping of efforts in unsystematical collecting of non-homogeneous data for each individual project. A proper knowledge of the country cannot be achieved in this manner, and the training of national personnel is adversely affected, as we shall see.

6. SECOND PHASE : Organizing each field.

a) We shall briefly indicate the principles that should govern the organization of each particular field and thus promote the specific projects mentioned earlier.

i) Unity of command is imperative. To scatter the various geological, hydrological or meteorological activities would lead to duplications and sterile competition. When developing natural resources, the personality of the man who will direct the work in each scientific field must be such that he can understand and appreciate at least in their wider outlines the problems and viewpoints of other fields. This man must, at all events, be practical-minded and determined as well as subtle enough to understand all difficulties that may arise.

ii) It is by no means necessary that this team leader be specialized in the field of the activity he directs. He must, however, be assisted by some experienced specialists and grant them full independance in their respective subject through adequate delegation of authority.

iii) Two kinds of activity will generally be distinguished in the organization od work : research in laboratories and observatories ; field measurements and observations. There is not much to be said about the first kind : they should be restricted to what is necessary and, if they are to be useful, they require the employment of trained specialists from outside, who will get down to work without waste of time. Those activities which are scattered throughout the country, observation posts or stations and field parties, will probably be the more important numerically : they will made wide use of national personnel.

b) The laboratory groups and field parties will necessarily be constituted around the experienced specialized staff. We consider that such staff may be quite small but must be very highly qualified. All the additional personnel should consist of scientists and technicians of the country concerned. And here it is necessary to make a few important remarks.

i) If technical assistance is to have durable effects and go beyond a mere task of setting up equipment, then the men of that country must, at every steps of the project, take the largest possible part in its implementation and in the responsabilities which it carries. The training of these men is, therefore, the crux of the problem.

ii) Let us leave the matter of the general school education, which takes time and does not concern us here, and consider the scientific or technical training which can be acquired by a man while taking part in the study and development of natural resources of his own country. For such training to be possible, the work must be organized accordingly and this may lead to fairly unorthodox solutions.

a. One should not aim at forming a team of highly qualified national university graduates who would undertake the various research subjects under the leadership of a specialist : this is neither realistic nor necessary. On the contrary, it is recommended that each research program be split into tasks in such a way that the level of general knowledge required to fulfill such takes is lowered. A bold spirit and an intelligent analysis of the actual operations can achieve this division of the work. The training of local personnel in very narrow fields can thus be obtained in a very short time. A body of such national specialists, led by a small number of highly qualified men who must be first class organizers, can produce the same research work as a team of expensive technicians and scientists imported at

great cost. The immense advantage of this formula is that men soon take part in the development of their country, with resulting pride and dignity. It can be safety said that no element creates better spirit of confidence and collaboration between the technical personnel of a young nation and the foreigners who provide technical assistance.

b. The organizing of this training has many aspects which all deserve consideration : psychotechnical selection specially designed for the work in view ; courses and practical training in specialized schools with very limited and precise curriculum ; incorporation after 3 to 6 months schooling, of the trainee in field parties conducting a particular type of work ; return to the specialized school after some time spent in such field work ; specialized training abroad and return to a laboratory or field team with an increase of technical responsibility, etc.

iii) Insistence must be placed upon the need for an official recognition of the qualification thus acquired by national personnel during their employment with the project of development. Technical assistance in the use of natural resources is not the proper agency for solving the whole problem of the country's education, but can contribute greatly to its solution. The men who have had the training described above, will justly expect an official recognition of their qualifications and adequate legislation should be brought about to ensure that these qualifications will be assimilated to some of the degrees or diplomas which are granted, or will be one day, by the national establishments of education.

c) The laboratories and field installations having been set up, the teams which process and interpret the data will now have to be organized. Special research or observations of less immediate interest will also be undertaken at this stage. And thus is reached the moment when the importance and nature of the development projects justify the establishment of proper national services, which will take their place in the world community of these services : the Specialized Agencies of the United Nations.

7. CONCLUSION

a) We have attempted to summarize the ideas upon which projects for developing natural resources should be based, when an emerging country requests technical assistance. We have stressed the need for a preliminary scientific survey so that it is possible to draw up a general plan of action which takes into account, with a sufficient degree of confidence, the inescapable factors of the ~~of the~~ environment. The choice of particular projects, among those which seem desirable, can be made with better chances of success and the detailed programs are set up with the collaboration of the team in charge of the preliminary survey.

b) The principle of an operation in two phases should not be rejected on the grounds that it is too slow and costly. Only a small number of specialists are required for the first phase if it is well planned and the coordination of research is a time-saving element. The global approach to the problems involved in the two phases permits the collection of a large amount of data relating to the natural environment : this is a considerable wealth which the development of the country will require sooner or later and the lack of which may paralyse the achievement of some projects.

c) Moreover, the thorough study of the natural environment, first undertaken for specific programs and later systematically extended to many subjects in each scientific discipline, is the only reasonable way of establishing national services and provides scientific and technical training for the local personnel.

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